EFFECT PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF HYDRATED LIME

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A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

A THESIS

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PREFACE

This paper is divided into two parts.

Part 1 deals with a discussion of the methods used in the mixing and testing laboratories and the results attained. It contains several sets of curves which give the average results of all tests.

Part 2 contains a complete set of laboratory data, which may be referred to should the results of any particular test be desired.

C.A.K.

L.D.H.

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PART 1

Containing a Discussion of the Methods Used in the Mixing and Testing Laboratories and the Results Attained.

INTRODUCTION

The increased use and importance of Portland cement as a building material has led to a discussion of the possibilities of improving certain of its characteristics. Compounds, which would waterproof Portland cement concrete, have been tried; adulterants have been added to decrease the cost, materials have been used to increase the plasticity of a Portland cement mortar, and various other improvements have been offered.

It had been attempted to strengthen lime mortar by adding Portland cement. This led to the attempt to cheapen cement mortar by the addition of slaked lime. Where the strength of a mortar was not the depending factor of any work, (as is often the case), it would seem that the use of large quantities of slaked lime in Portland cement would be of little moment. There were other advantages which seemed to be gained by the addition of lime to Portland cement.

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It was not, however, until the increased production and use of the hydrated lime brought attention to the possibilities of its use that the issue was entered into deeply. Hydrated lime,is by far a more superior material than ordinary slaked lime, is a fine, dry, white powder which, as its name indicates, is quick lime already hydrated. It may be used for any purpose which lump lime is used for. The hydration being mechanical is more complete and uniform than the hydration of lump lime. There are not the small particles of free lime in a properly made hydrate that there are in lump lime. This as we know, is a very important feature. Hydrated lime is at present the only material which seems to favorably affect several properties of Portland cement. Because of this, attention has been forcibly called to the use of the two as a mixture.

The lack of plasticity of a Portland cement mortar does not allow the use of a pure

mortar in general practice. It has been observed everywhere that it is difficult to get a laborer to mix it sufficiently. By the addition of lime it was early noted that the plasticity was so increased as to render the mixing comparatively easy. Troweling is also made easier and better work results when lime has been added to the mortar.

Where a construction, necessitating the handling of concrete chictes, is in progress, the difficulty and labor expense encountered in keeping the chute clear and the concrete in motion often materially increases the cost of the work. The concrete will not stay in a mass but will scatter and, in a sticky manner, retard the flow in various places. The addition of lime to the concrete seems to act as a lubricant for the concrete stays in a connected mass and flows freely through the chutes.

We know that the richer a concrete, the less permeable it is. If there we should want an impermeable concrete, an excess of cement

should be used. This is of course practically impossible owing to the cost issues and the fact that rich concretes are more subject to check cracking and are far less constant in volume, under atmospheric changes, than are the weaker concretes. This increased impermeability is undoubtedly due to the void filling properties of the finely ground cement.

Thomson states that, of the finer particles in a mortar, those below the No. 40 sieve affect the permeability much more than the others. It seems then, reasonable to assume that the finer the particles, the more effect they will have on the permeability of a mortar.

Portland cement is a sandy product as compared to the fine hydrated lime. If the addition of hydrated lime to concrete makes the concrete less permeable, we can, then attribute a large part of the success to the finely divided particles of lime. In a series of tests on damp-proofing and water-proofing compounds

made by the Bureau of Standards of the Department of Commerce and Labor, the results of the hydrated lime adulterant were among the best.

There may be some chemical action which makes the combination of hydrated lime and Portland cement less susceptible to the flow of water, but in all probability the void filling property of the lime is the chief reason.

The conclusion of Thomson and many other investigators is that the addition of hydrated lime increases the water tightness or impermeability of the concrete.

The use of concrete for road work is becoming more extended each year. One of the difficulties of concrete road construction is the fact that the top and often the bottom are covered with hair cracks. Mr. R. S. Edwards attributes the hair cracks to the following causes:

While the cement is setting, the moisture near the lower surface is being absorbed by the

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ground and that from the upper surface it is being evaporated. Thus before final set, some of the moisture necessary to the setting of the cement is lost, consequently a layor at the top and at the bottom is of less strength than the concrete in the middle of the section. If we could incorporate some material in the concrete, which would hold a surplus of water until the set is completed, we would here have a valuable adjunct to concrete, particularly when used under conditions such as those of road construction. Mr. Edwards maintains that hydrated lime serves this purpose in concrete. The matter should at least bear further investigation.

The preceding paragraphs show the many advantages to be gained by the addition of hydrated lime in Portland cement. Should these benefits be attained without any particular decrease of the strength properties of Portland cement, then we will have something of immense

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commercial value.

As no complete tests on this phase of the subject have as yet been published, the writers have attempted in this paper to determine the effects in tension and compression produced by the addition of various percentages of hydrated lime to Portland cement mortars, taking as mixes the most common mortars, 1:2 and 1:3. A parallel set of tests was also made on neat cement test pieces for comparative purposes.

With the above in view, this paper is submitted.

LABORATORY EQUIPMENT AND APPARATUS USED

The laboratory equipment consisted of trowels, scales, beakers, graduates, pans, glass plates and every other thing necessary to carry on the work laid out.

The materials used were stored in watertight and almost airtight steel receptacles, so that there was little chance of foreign materials or moisture affecting them during the period of laboratory work.

The mixing plates were of glass, 20"x 30" in size. The gang moulds were of brass; the compression pieces being one inch cubes and the tension pieces of standard form as shown in figure 1. The moist cabinet was a receptacle, about 25" x 32" x 42", with a four inch water pan at the bottom. The pans for storage of the test pieces, after the twenty-four hour period, were 20" x 30" x 5" in depth.

The apparatus used for the specific gravity test consisted of the standard Le Chatelier's

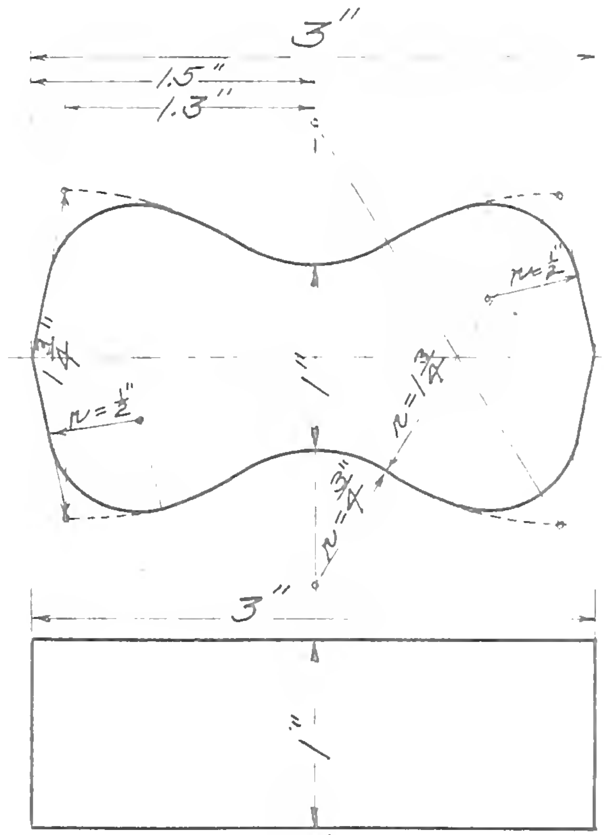
specific gravity apparatus. The normal consistency of the neat paste was determined by means of a Vicat needle, similar to that in figure 2.

The accelerated test on the pats was made in a steam oven, about 5" x 30" x 15" in size, with shelves above the water line so that the pats were continually kept in a steam bath.

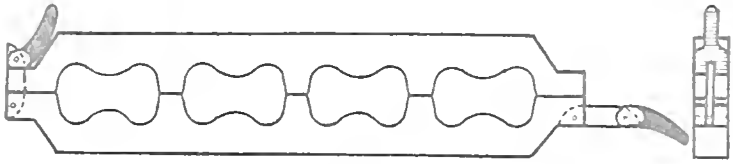
A temporary apparatus was erected to determine the density of the hydrated lime and the Portland cement. The "45 degree" method is shown in figure 3 and the "Sieve" method in figure 4.

The machine used for testing the briquettes was a 1000# Riehle shot machine similar to that shown in figure 5. The cubes were tested in a 10000# Olsen testing machine, shown in figure 6.

A - Details for Briquette
B - Details for Gang Mould



A



B

Figure 1.

Figure 2

"45°" METHOD

Determination of Density of Lime and Cement

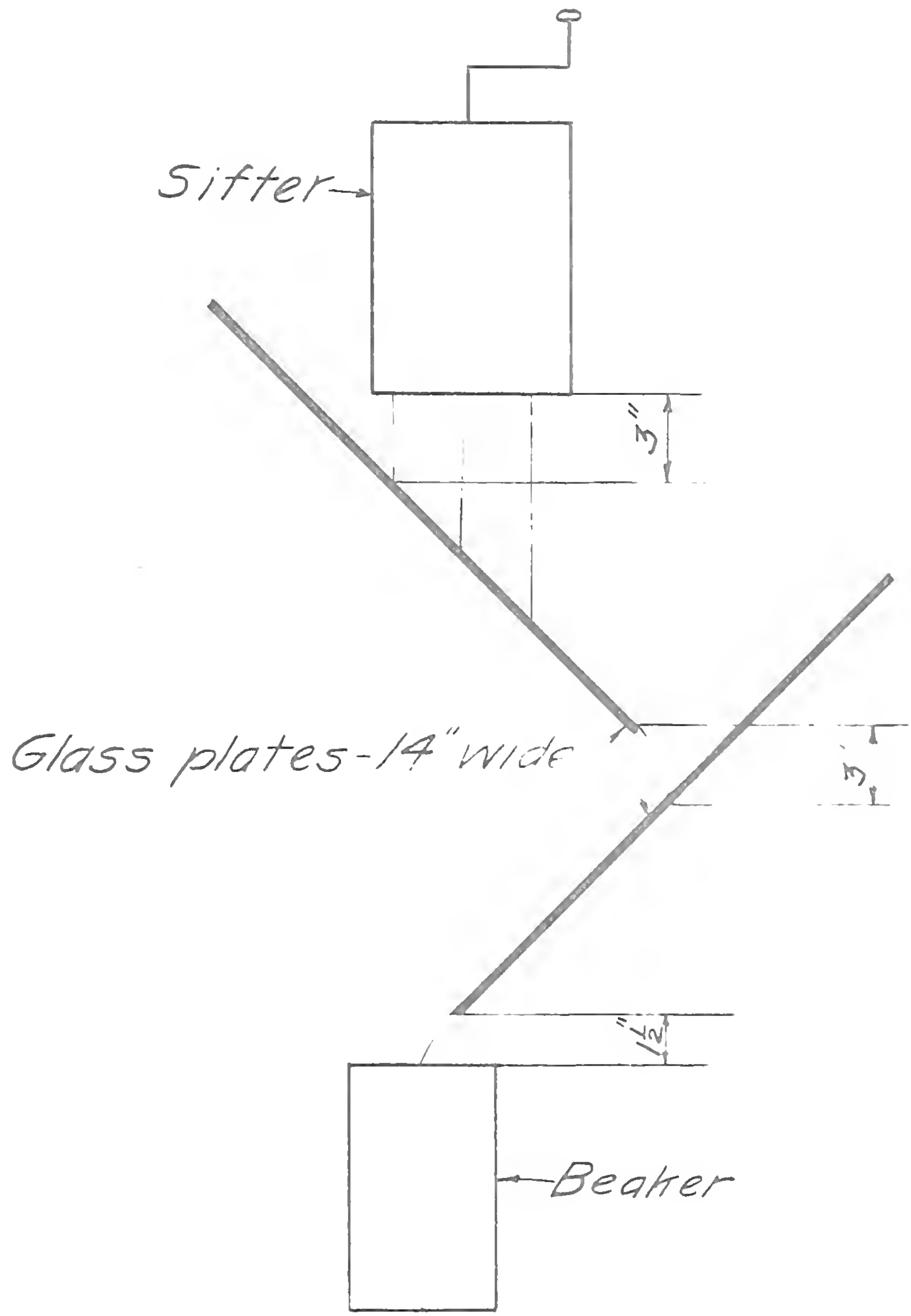
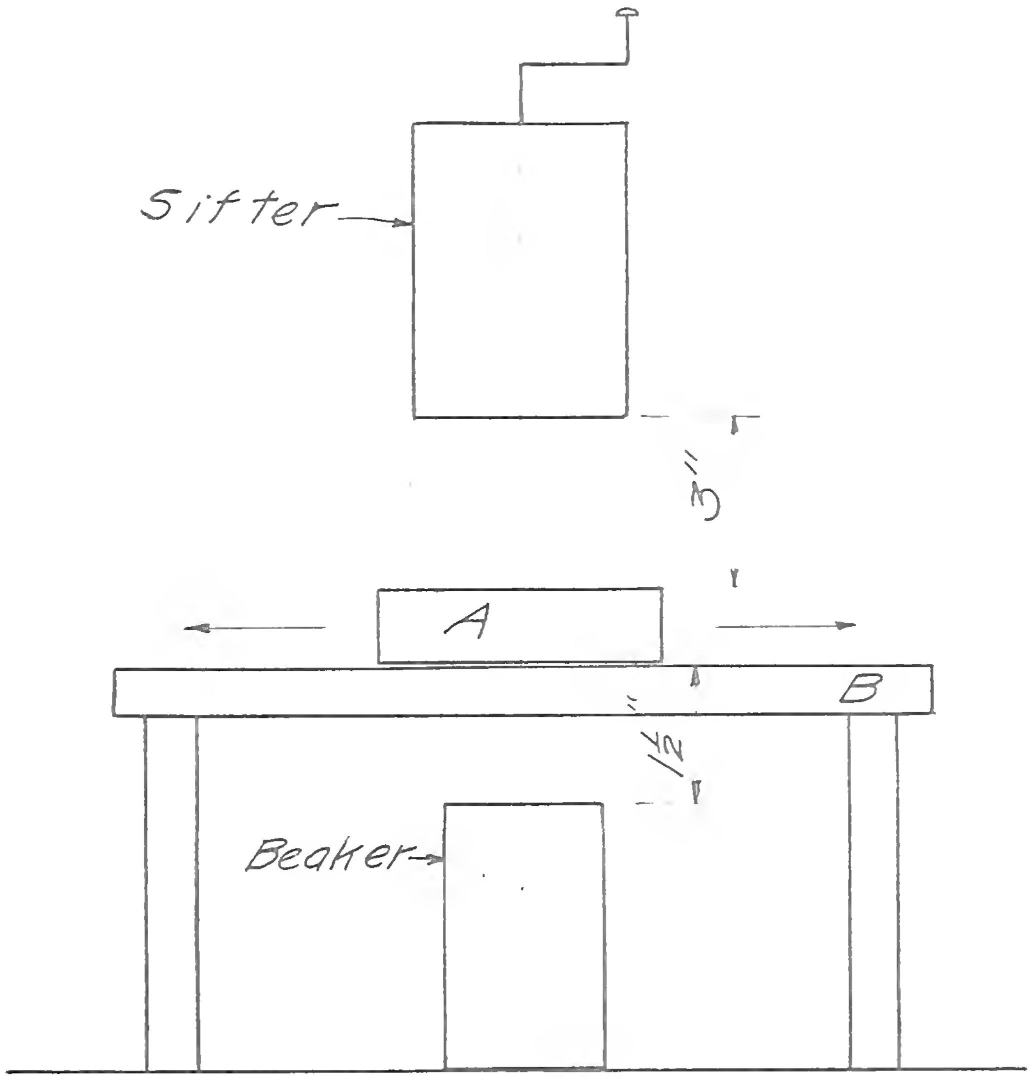


Figure 3

"SIEVE" METHOD

Determination of Density of Lime and Cement



Sieve A moved horizontally on bars B allowing material to fall through to Beaker.

Figure 4

Figure 5

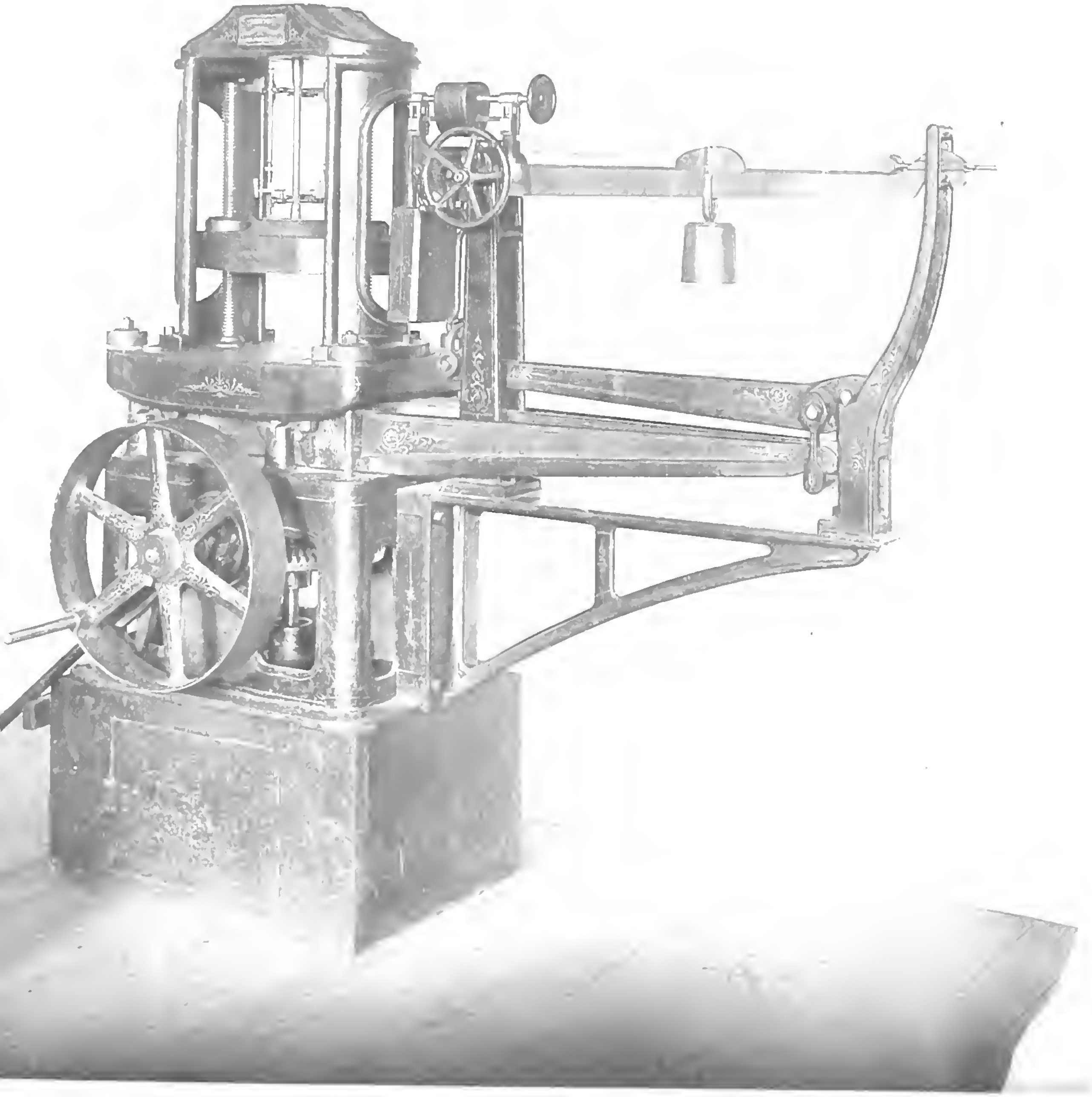


Figure 6

MATERIALS USED

The Portland cement used was from the Mitchell Mills of the Lehigh Portland Cement Company and had the following chemical composition:

Silica - - - - - - - -	21.50%
Oxide of Iron / Alumina - - -	8.84%
Oxide of Lime - - - -	62.09%
Oxide of Magnesia - -	3.06%
Loss, SO_3 - - - - -	1.47%

The following figures relative to the Portland cement are the average results of two determinations.

Specific gravity - - - 3.10

Fineness -

4.1% retained on No. 100 sieve

18.2% retained on No. 200 sieve

Normal consistency - - -24%

Time of initial set - 3 hrs. 15 min.

Time of final set - - 4 hrs. 15 min.

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The cement for these tests was taken direct from bin without being previously ignited.

The lime used was the Mitchell Lime Company's hydrate of the following chemical composition.

Calcium Oxide - - - -	72.70%
Silica) Iron and Alumina) - -	1.44%
Magnesium oxide - -	1.59%
Sulphuris - - - - - -	.69%
Loss - - - - - - - -	23.42%

The fineness of the lime as determined by two tests was as follows:

0.6% retained on the No. 100 sieve

0.95% retained on the No. 200 sieve

Note: The residue on the No. 100 sieve was discolored and was apparently largely foreign material.

The sand used was standard Ottowa sand, screened to pass a No. 20 sieve and be retained on a No. 30 sieve.

DESCRIPTION OF TESTS

Proportions

The tests were made on mortars of one part cement and lime to two parts sand, and one part cement and lime to three parts sand. A parallel set of tests was also made on neat cement test pieces. The addition of stone should cause no change in results if added in such proportions that the voids are properly filled.

The proportions used were taken according to weight measurement, the total of lime and cement being taken as one part of the mixture to a definite number of parts of sand. In the laboratory data given in Part 2, the lime is taken as a certain percentage of the cement. Should it be desired to convert the lime percentage into a percentage of the total lime and cement, the curve and table of Plate 1 may be used. The curves of Plates 6 to 17 inclusive give the strength in terms of the percent of the total lime and cement. The volume rela-

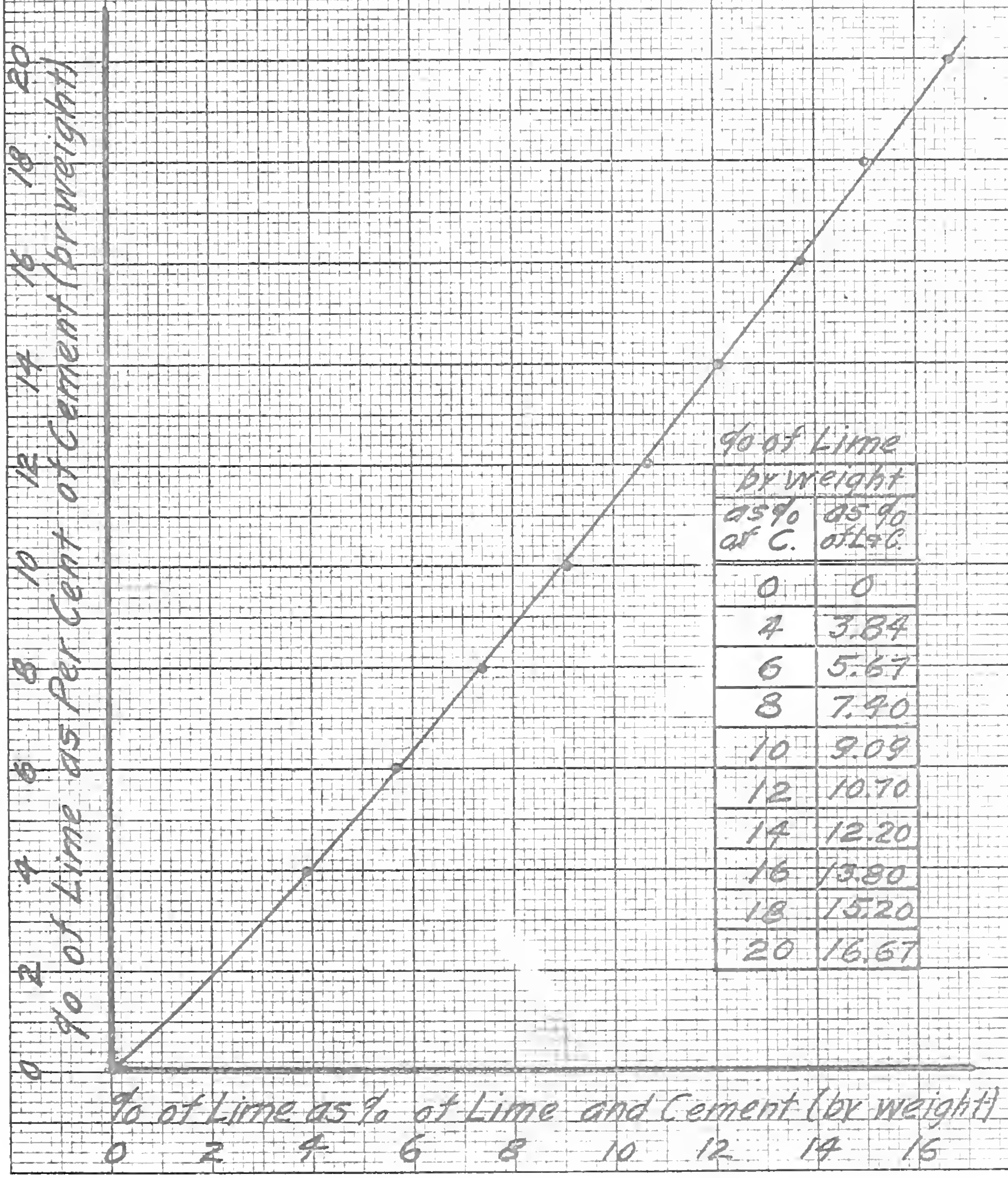
tions are shown in the curves of Plates 18 to 23 inclusive.

On some jobs, volume measurements are used. In order that the results obtained might be given in terms of volume measurements, the density of the lime and cement was determined. While these densities may not be strictly correct, yet they are relatively correct, since the lime and cement determinations were made by the same methods and under the same conditions. An average of six determinations by two methods was taken as the correct density of the lime and cement. The data for the "sieve" method follows:

	Wt. of lime and beaker	Wt. of beaker	Wt. of Lime
1.	212.1	100.2	111.9
2.	211.6	100.2	111.4
3.	211.5	100.2	111.3
4.	210.5	100.2	110.3
5.	212.0	100.2	111.8
6.	212.7	100.2	112.5
		Average	111.56

PLATE 1

Curve Showing Relation Between Percentage of Lime, as Per Cent of Cement (by weight) to Per Cent of Lime and Cement (by weight)



% of Lime by weight	
as % of C.	as % of L+C.
0	0
4	3.84
6	5.67
8	7.40
10	9.09
12	10.70
14	12.20
16	13.80
18	15.20
20	16.67

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	Wt. of Cement and beaker	Wt. of beaker	Wt. of Cement
1.	418.9	100.2	318.7
2.	420.6	100.2	320.4
3.	420.4	100.2	320.2
4.	422.6	100.2	322.4
5.	424.1	100.2	323.9
6.	435.0	100.2	329.8
		Average	322.5

The "sieve" method is shown in the sketch of figure 4. The "45 degree" method is shown in the sketch in figure 3. Note the height of fall is the same in both methods. This was done to insure a uniformity of results. The data for the "45 degree" method follows:

	Wt. of Lime and beaker	Wt. of beaker	Wt. of Lime
1.	211.3	100.2	111.1
2.	210.4	100.2	110.2
3.	211.85	100.2	111.65
4.	208.6	100.2	108.4
5.	209.3	100.2	109.1
6.	210.6	100.2	110.4
		Average	108.47

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Note: Weights are given in grams.

The weight of the beaker was taken as the average of three weighings.

The average value of the lime by the two methods was taken as 110.0 grams.

The volume of the beaker was taken as 275 cc., the average of two determinations.

From the above data, the density of the lime and cement was determined as follows:

Wt. of cement $\dfrac{322.5}{275} = 1.17$ gms/cc.

Wt. of lime $\dfrac{110.0}{275} = 0.4$ gms/cc.

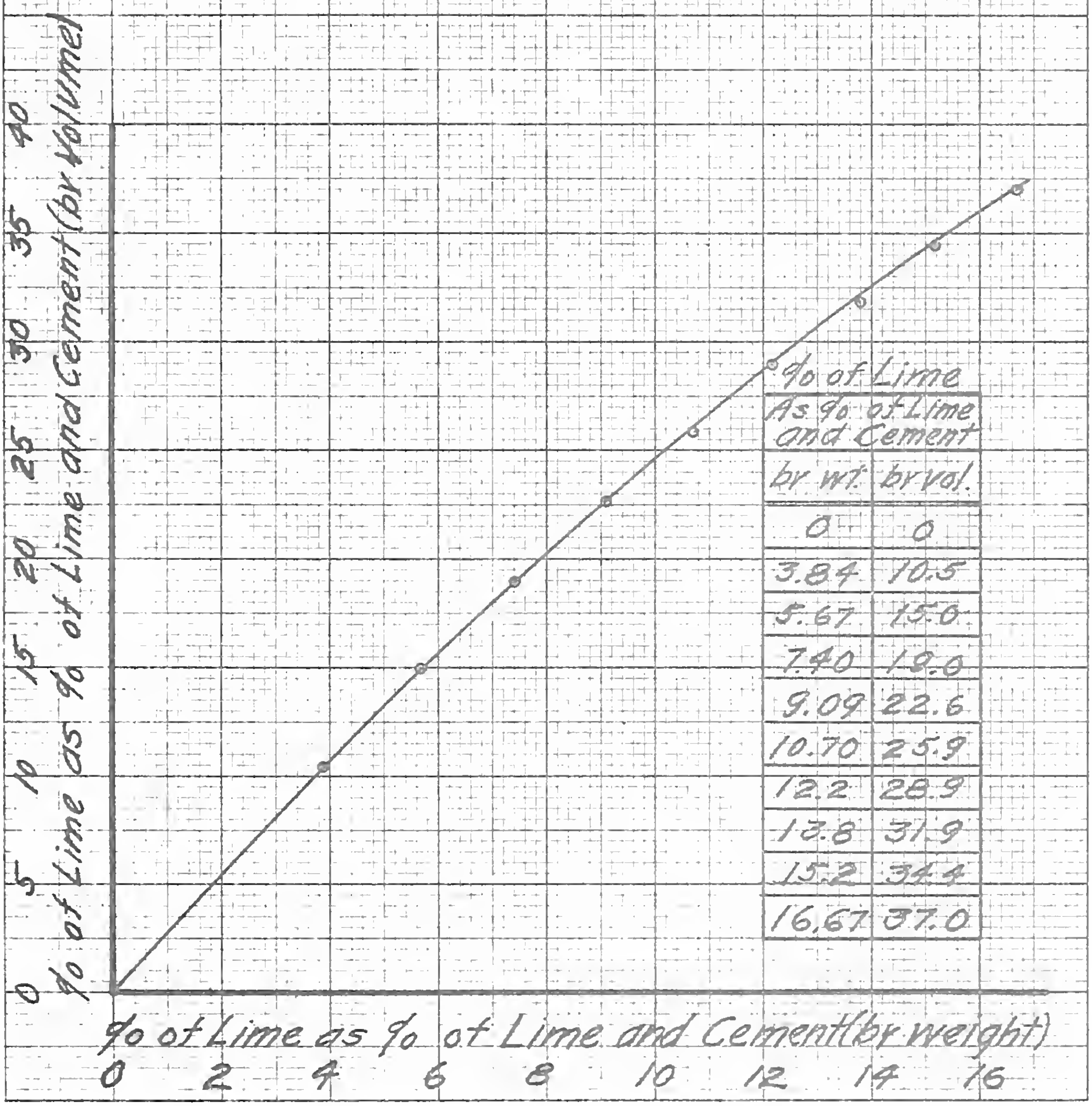
$$\frac{0.4}{1.17} \times 100 = 34.15\%$$

Density of lime is 0.3415 as compared with cement.

The curve and table of Plate 2, shows the relation between the percent of lime (by weight) of the total lime and cement. The curves in figures to inclusive give the strength results in terms of the percentage of lime by

PLATE 2

Curve Showing Relation Between Percentage of Lime, as % of Lime and Cement (by Volume) to % of Lime and Cement (by Weight)



% of Lime As % of Lime and Cement by wt.	% of Lime As % of Lime and Cement by vol.
0	0
3.84	10.5
5.67	15.0
7.40	19.0
9.09	22.6
10.70	25.9
12.2	28.9
13.8	31.9
15.2	34.4
16.67	37.0

volume.

The formula used for converting the weight measurements was derived as follows:

Let m = reciprocal of density of cement

Let km = reciprocal of density of lime

mx % of cement (by wt.) = vol. of cement = X

kmx % of lime (by wt.) = vol. of lime = Y

Total vol. of lime and cement = X + Y

Proportion (by vol.) of lime = $\frac{Y}{X + Y}$

$\frac{1}{m} = 1.17 \qquad m = 0.855$

$\frac{1}{km} = 0.4 \qquad km = 2.5$

Example:

% of cement (by wt.) of total lime and cement = 96.16

% of lime (by wt.) of the total lime and cement = 3.84

$.855 \times 96.16 = 82.216 = X$

$2.5 \times 3.84 = 9.6 = Y$

$\frac{9.6}{82.216 + 9.6} \times 100 = 10.5\%$ or percentage of lime (by vol.) of the total lime and cement.

HYDRATED LIME IN PORTLAND CEMENT

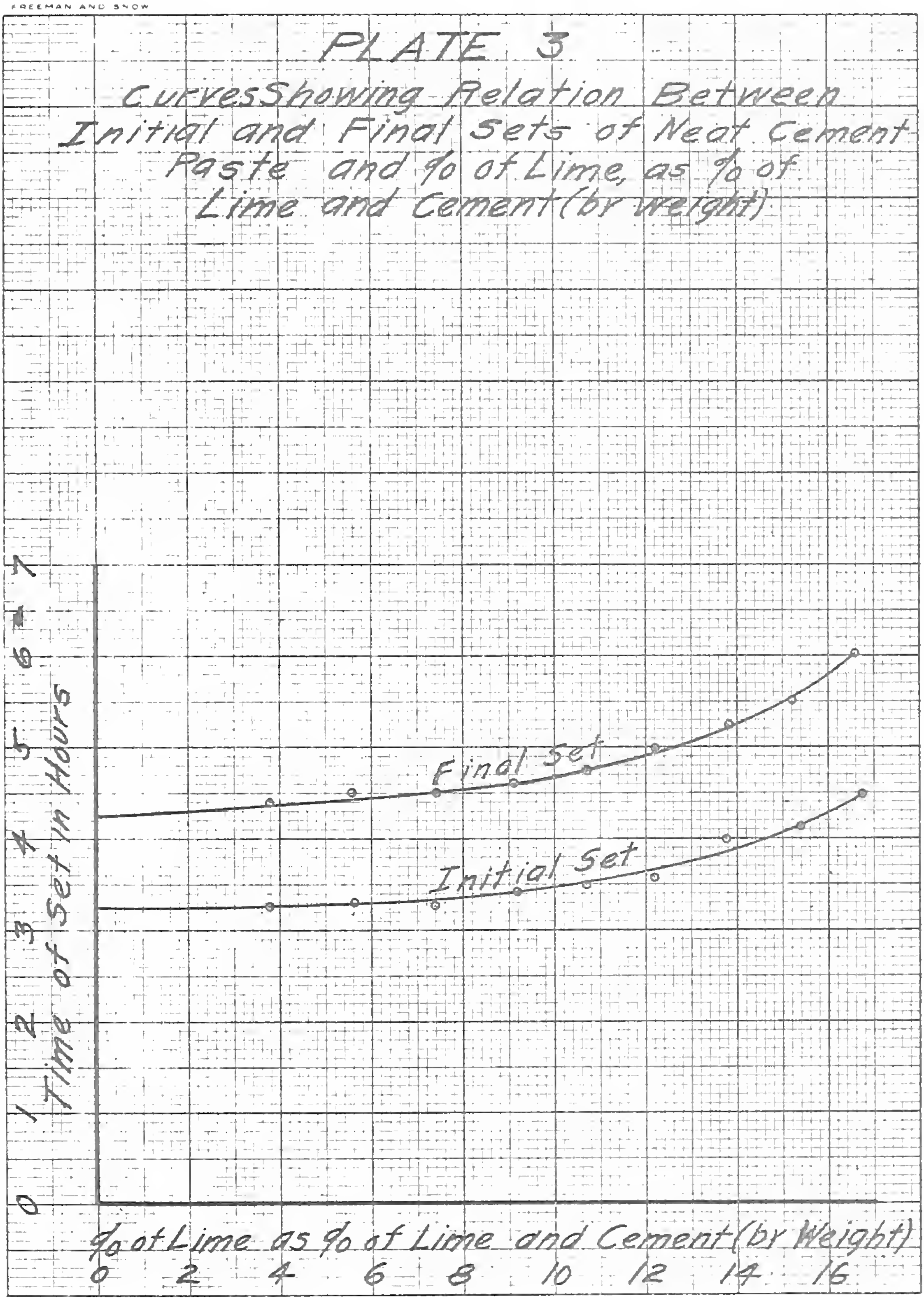
Time of Set

The addition of lime to the neat paste increased the time of initial and final set as shown in the curves of Plate 3.

Consistency

The normal consistency of all neat pastes was determined by means of the Vicat apparatus, shown in figure 2. The effect upon the normal consistency of the cement produced by the addition of lime is clearly shown in the data. The gradual increase is shown at a glance by referring to the curve of Plate 4.

Feret's percentage of water for Portland cement mortar of standard consistency, tabulated in Plate 5, was used in determining the consistency of mortars. These figures agree very closely with the results of formulas commonly used to obtain this result. The mortars were in all cases of a quaking consistency; water could easily be brought to the surface under the pressure of the trowel.


FREEMAN AND SNOW
PLATE 3
Curves Showing Relation Between Initial and Final Sets of Neat Cement Paste and % of Lime, as % of Lime and Cement (by weight)
Final Set
Initial Set
Time of Set in Hours
0
1
2
3
4
5
6
7
% of Lime as % of Lime and Cement (by Weight)
0
2
4
6
8
10
12
14
16

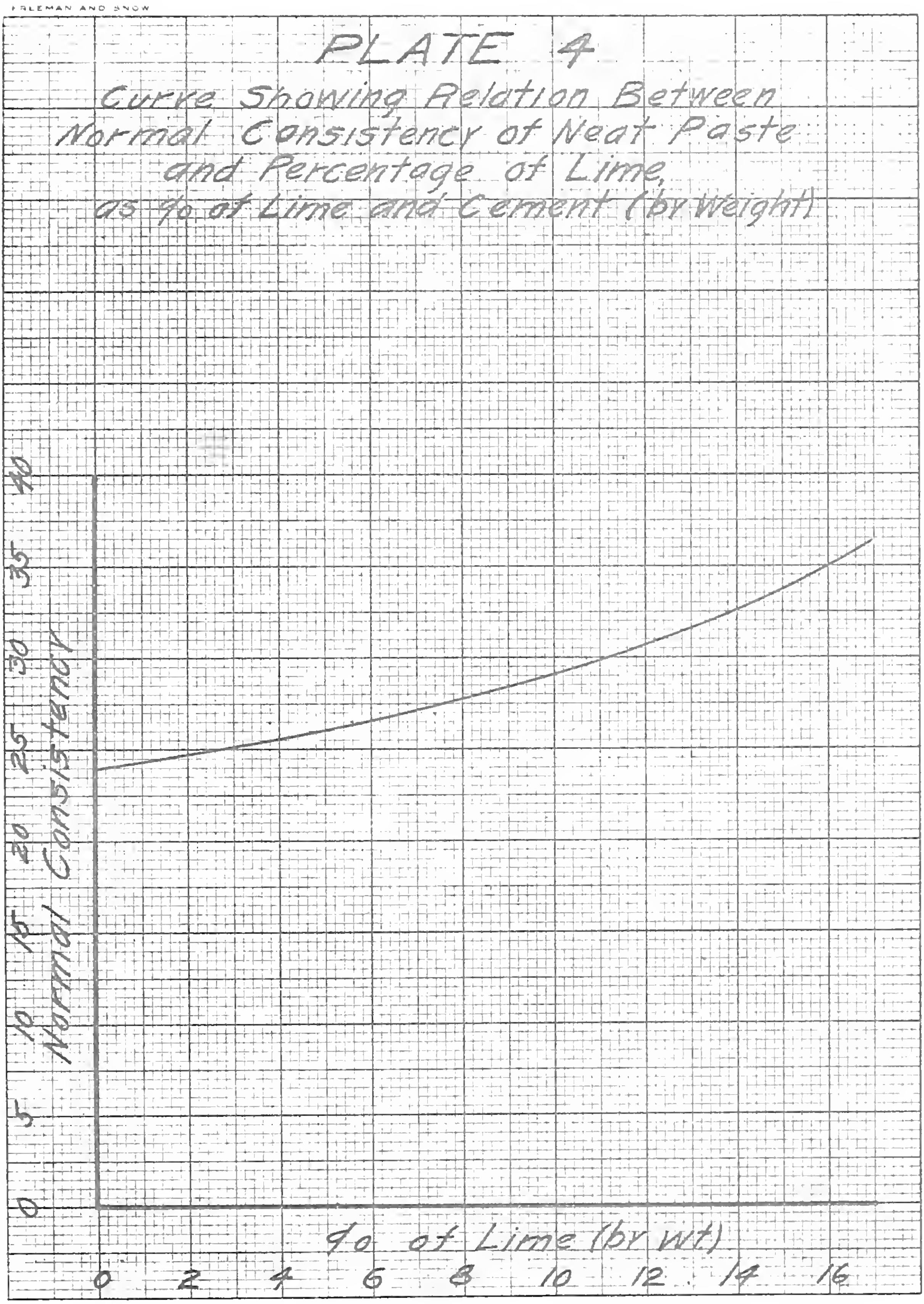

FREEMAN AND SNOW
PLATE 4
Curve Showing Relation Between
Normal Consistency of Neat Paste
and Percentage of Lime,
as % of Lime and Cement (by Weight)
Normal Consistency
0
5
10
15
20
25
30
35
40
% of Lime (by wt)
0
2
4
6
8
10
12
14
16

PLATE 5

Feret's Percentages of Water for Portland Cement Mortar of Standard Consistency

% of Neat Cement Motar	Per Cent of Water in Terms of Cement and Sand				
	1:1	1:2	1:3	1:4	1:5
18	12.0	10.0	9.0	8.4	8.0
19	12.3	10.2	9.2	8.5	8.1
20	12.7	10.4	9.3	8.7	8.2
21	13.0	10.7	9.5	8.8	8.3
22	13.3	10.9	9.7	8.9	8.4
23	13.7	11.1	9.8	9.1	8.5
24	14.0	11.3	10.0	9.2	8.6
25	14.3	11.6	10.2	9.3	8.8
26	14.7	11.8	10.3	9.5	8.9
27	15.0	12.0	10.5	9.6	9.0
28	15.3	12.2	10.7	9.7	9.1
29	15.7	12.5	10.8	9.9	9.2
30	16.0	12.7	11.0	10.0	9.3
31	16.3	12.9	11.2	10.1	9.4
32	16.7	13.1	11.3	10.3	9.5
33	17.0	13.3	11.5	10.4	9.6
34	17.3	13.6	11.7	10.5	9.7
35	17.7	13.8	11.8	10.7	9.9
36	18.0	14.0	12.0	10.8	10.0
37	18.3	14.2	12.2	10.9	10.1
38	18.7	14.4	12.3	11.1	10.2
39	19.0	14.7	12.5	11.2	10.3
40	19.3	14.9	12.7	11.3	10.4
41	19.7	15.1	12.8	11.5	10.5
42	20.0	15.3	13.0	11.6	10.6
43	20.3	15.6	13.2	11.7	10.7
44	20.7	15.8	13.3	11.9	10.8
45	21.0	16.0	13.5	12.0	11.0
46	21.3	16.1	13.7	12.1	11.1

HYDRATED LIME IN PORTLAND CEMENT

Mixing

All materials were weighed. The cement and lime were spread evenly on the glass plate and mixed dry beforeadding the sand. The aggregate was again mixed dry after the sand was added. A crater was then made in the center and the proper percentage of water added. The materials were turned from the outer edge into the crater with the aid of the trowels, until all the water was absorbed. The mass was then kneaded for about two minutes when it appeared to be perfectly mixed. A single batch, of approximately 3000 grams, was mixed to make fifteen briquettes, fifteen cubes and from three to five pats.

All batches were mixed by the same man who attempted a uniformity of procedure.

Moulding

The moulds, with inner surfaces oiled, were placed on glass plates. The paste or mortar was pressed into the moulds, care being taken

to put the same pressure on each test piece, and the surface struck off and smoothed with a trowel.

Storage

All test pieces were kept in the moist cabinet for approximately twenty-four hours, the exact number of hours being noted on the data sheets. The moulds were then removed and the one-day test made. The remaining test pieces were kept immersed in water in the storage pans until tested. One pat was kept immersed in water and one exposed to the air, and observed at intervals for any track of cracking, distortion, checking or disintegrating.

Testing

The one-day test was made as soon as the moulds were removed. The other tests were made as soon as the test pieces were taken from the pans, on the proper day. Three test pieces of each batch were tested, one day, seven days, and twenty-eight days after date of mixing, an average of three being taken as the correct value.

HYDRATED LIME IN PORTLAND CEMENT

The test pieces were tested in the machines previously noted. The cubes were placed on a ball and socket block and between two blotters so that the pressure would be more evenly distributed.

Besides the pats previously mentioned, after being in the moist cabinet for twenty-four hours, a third pat was placed in a steam bath for five hours and observed for the same defects as were noted in the others.

RESULTS OF TESTS

As previously mentioned, all the data has been plotted in the form of curves. It is not claimed that these curves are perfectly accurate, i.e., drawn thru the exact points. Under the assumption that the results would be more or less uniform, the curves were drawn to represent a fair average of the points plotted. Only after careful investigation were they drawn.

Although there were several departures from expected results, yet it may be said that they were, in general, uniform.

The form and evenness of texture of the briquette were highly satisfactory, being exceedingly uniform.

Owing to shrinkage, (especially in the pieces containing the higher percentages of lime) and the small size of the cubes, it was noticed that some of the pieces were not true cubes.

Lack of uniformity, in the tests of the cubes (though not seriously so) may be partly

attributed to this.

As could be deduced from the above, it was noticed that the amount of shrinkage in setting increased with the percentage of lime added. With the exception of the two highest percentages of lime in the neat cement, however, the pats showed no signs of cracking or disintegrating in either the water, air or accelerated tests.

The one-day tests were not as satisfactory as the other tests, though they were up to standard.

The Standard Specifications for Portland Cement adopted by the American Society for Testing Materials and other engineering societies, contains the following paragraph on

TENSILE STRENGTH

"The minimum requirements for tensile strength of briquettes, one square inch in cross section, shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

HYDRATED LIME IN PORTLAND CEMENT

Age	Neat Cement	Strength
24 hours (in moist air)		175#
7 days (one day in moist air, 6 in water)		500#
28 days (one day in moist air, 27 in water)		600#

One Part Cement, Three Parts Standard Ottowa Sand

7 days (one day in moist air, 6 in water)	200#
28 days (one day in moist air,27 in water)	275#

By refering to the curves of Plates 6, 7 and 8, it will be seen that the addition of 12% (by weight) hydrated lime, does not weaken the neat paste enough to bring the tensile strength below the minimum allowed value. It is also shown that the addition of 8% hydrated lime to the 1:3 mortar gives strength results above the standard requirements.

No increase in tensile strength which some investigators say should result, was noted when small percentages of hydrated lime were added to the cement mortar.

It may be taken as a general rule, that the

compressive strength of a material increases with the tensile strength. Merriman gives the compressive strength of one month old neat Portland cement paste as 3000 pounds per square inch. By refering to the curves of Plate 10, it will be seen that with the addition of 16-2/3% (by weight) of hydrated lime, the value of neat cement is 3000 pounds per square inch. Merriman gives the strength of hydraulic mortars as 6 to 10 times the tensile strength. The standard German specifications require the compressive strength of concretes and mortars to be at least ten times their tensile strength. In the compression curves, it will be seen that the compressive strength exceeds in the majority of cases the tensile strength in the proportion of more than 10 to 1. This agrees very favorably with the above three statements.

It was found in both the neat paste and cement mortar tests, that the compressive strength increased with a small addition (4 or

5%) of hydrated lime.

Enough test pieces were made to complete the three months and one year test (previously mentioned) but only enough time has elapsed to allow of a few three months tests. It is possible that some interesting results showing a fair increase in strength after the three months period, will be developed. This would, though, be more apt to occur, were the pieces allowed to set in the air since it is a known fact that the final set of lime occurs a long time after being placed, and only in air.

CONCLUSION

We have seen that by the addition of hydrated lime to Portland cement, the following benefits resulted:

1. Increased plasticity, which

a) destroys the excess friction caused by the angular sand and stone particles, hence it becomes a lubricant.

b) makes mixing easier, hence cheaper labor expense and a better mix.

c) allows an easier flow, hence better for chute work, etc.

d) causes concrete to automatically fall into place, hence eliminating "stone pockets" and making certain of a complete covering of steel reinforcing.

2. Increased density, which

a) makes the concrete more water-proof, hence, the alternate wetting and drying, so detrimental to all concrete work, is largely eliminated. (Note: The Bureau of

HYDRATED LIME IN PORTLAND CEMENT

Standards found hydrated lime to be the best adulterant, as concerns the impermeability of the cement, on the two weeks tests.

b) Increases the hardness or toughness, hence of particular value in road construction.

c) Eliminated white efflorescence of salts.

d) Gives whiter and more uniform color, (Haff).

3. Keeps an excess of moisture in concrete, thus

a) Holding enough moisture to allow a complete set of the comparatively slow acting cement combination.

b) Helping to prevent hair cracks on surface, due to lack of moisture.

In adding lime, we are adding a material which is in itself "mildly cementitious", and which (since both Portland cement and hydrated lime are neutral) causes no unknown or uncertain

chemical actions to be set up, (Warner). Thus there need be no fear that some new action will take place.

The results of these tests show a gradual decrease in the tensile strength of Portland cement mortars, by increasing the proportion of hydrated lime. This decrease is not, however, of sufficient amount to condemn the use of hydrated lime in Portland cement. The advantages gained by its use are so numerous and of such great value, that they more than counterbalance the slight decrease in strength, (i.e. when the hydrated lime is used in the proper proportions).

It should be remembered that the kind of lime and cement used will materially affect the results. By refering to the chemical analysis of the lime and cement used, (see "Materials Used"), it will be seen that when we added the hydrated lime to the Portland cement, we added a lime high in calcium oxide to a cement already high in calcium oxide. Different results would

most likely be obtained if a low calcium lime or cement, or a high dolomitic lime was used.

The fact that both the lime and cement were high in CaO, may account for the lack of increased tensile strength, which some investigators say should result from the addition of small percentages of hydrated lime to Portland cement.

Some investigators claim an increased, others a decreased strength of mortars containing hydrated lime, when the mortar is allowed to set under water. This varies with the percentage of lime. A mortar with a high percentage of lime will not set at all under water. In foundation work, it is then not desirable to have too much lime present, even though the strength required is not high.

In conclusion, the writers' wish is to strongly recommend the use of hydrated lime in Portland cement mortars and concrete, when used in the proper proportion. It is not advisable to use a leaner mix and add hydrated lime to

HYDRATED LIME IN PORTLAND CEMENT

keep the impermeability or other properties of the cement the same as those of a richer mix without the addition of the lime, but, with the same richness or mix, the adding of lime is highly desirable.

On unimportant work, a fairly high percentage of lime may be used. In the more important engineering jobs, where the strength is an important factor, the use of 12% (by weight), equivalent to about a 14% replacement of cement, of hydrated lime, will not lower the tensile strength below the minimum requirements.

Higher percentages may be used, depending on the character of the work.

Where it is desired to limit the use of hydrated lime within the requirements of the specifications on a job, the conditions under which the concrete is to be used, the kind of lime and cement used, and the strength required must be thoroughly investigated. When this is done, complete satisfaction will result.

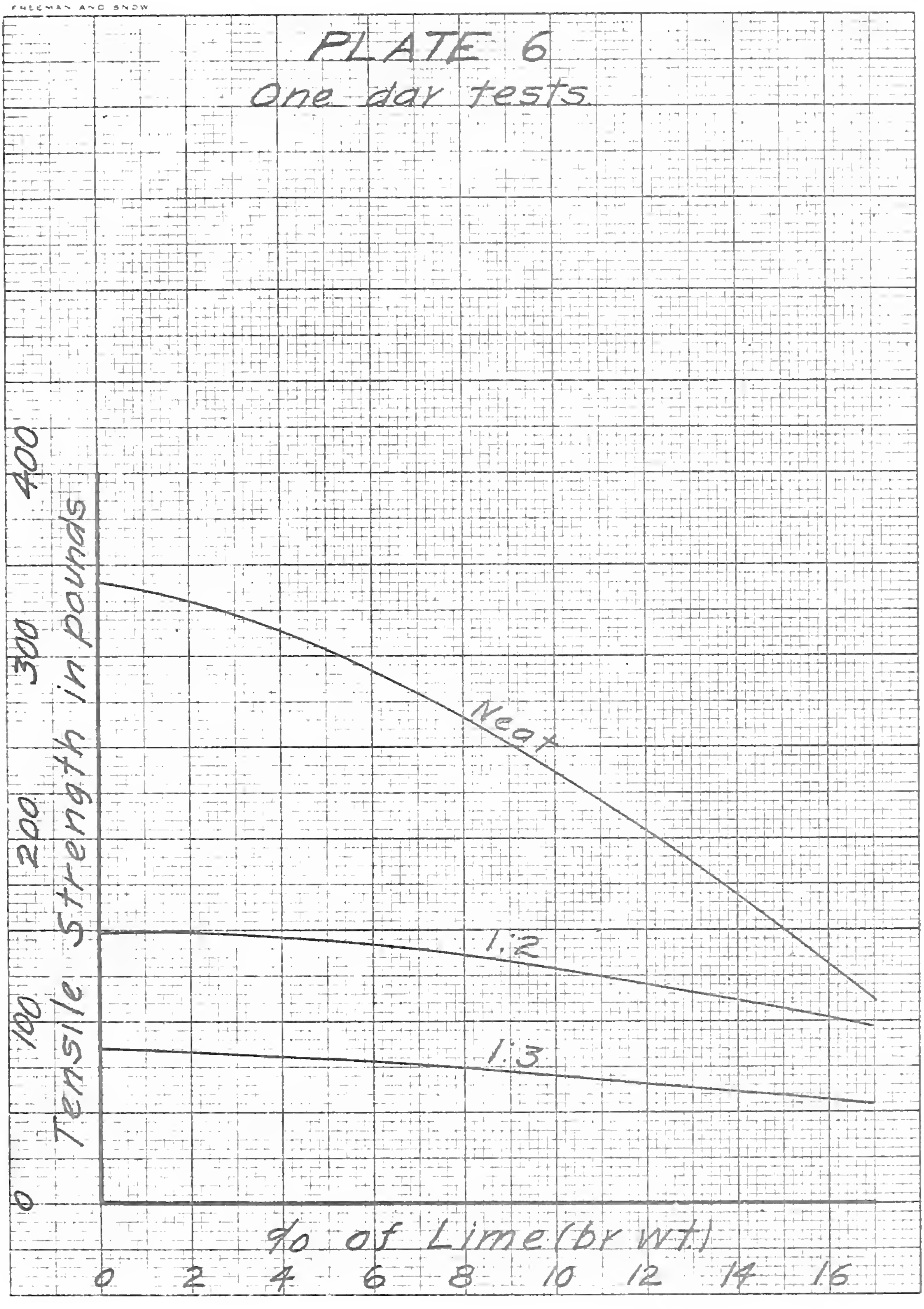
HYDRATED LIME IN PORTLAND CEMENT

The writers hope that these experiments will be continued, taking among other things, the following into consideration:

1. Effect on the strength when the test pieces are allowed to set in air.

2. Effect on the strength by the addition of various percentages of dolomitic hydrated lime when the test pieces are allowed to set in water and in air.

STRENGTH CURVES


FREEMAN AND SNOW
PLATE 6
One day tests
Tensile Strength in pounds
400
300
200
100
0
Neat
1:2
1:3
% of Lime (by wt.)
0
2
4
6
8
10
12
14
16

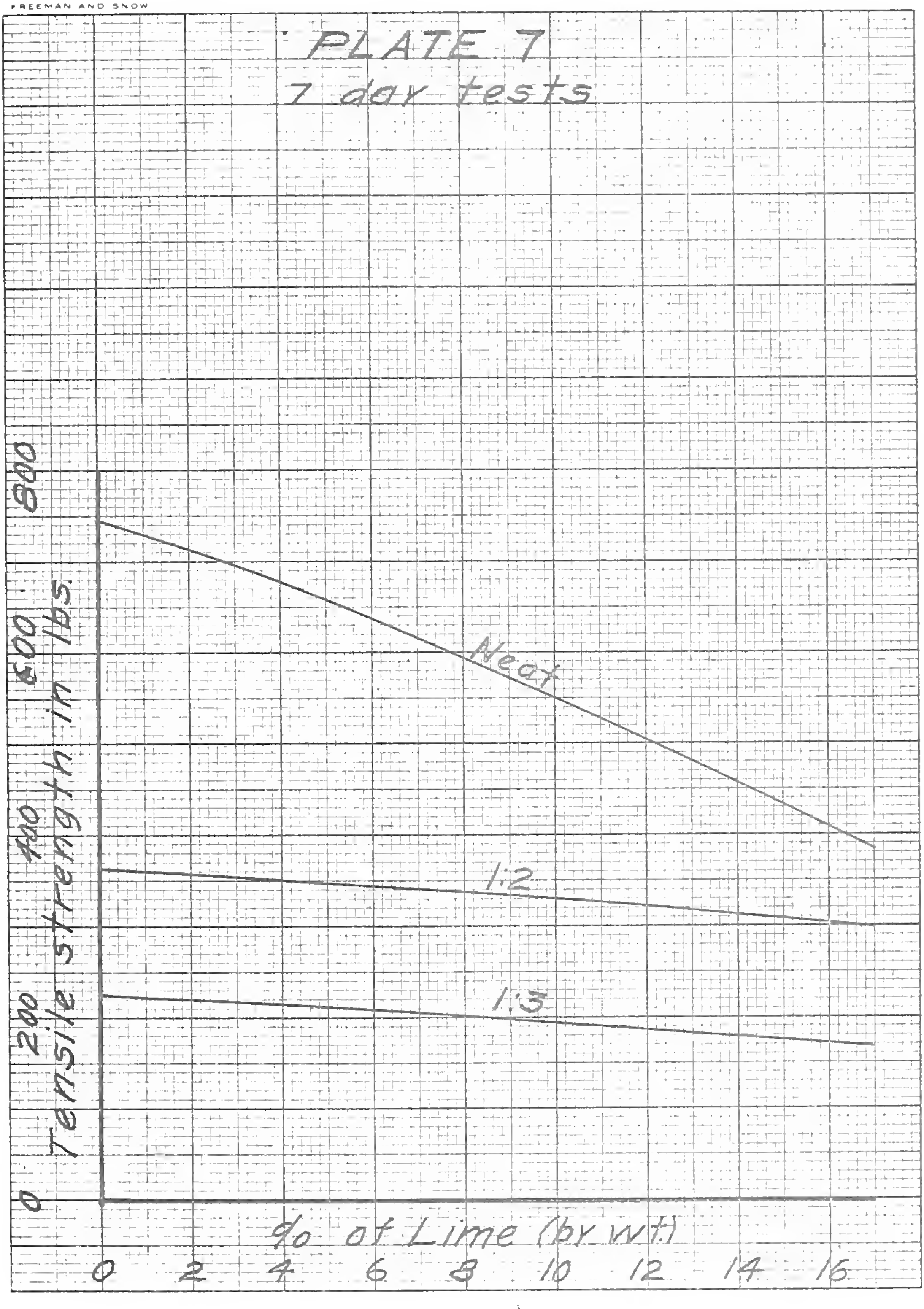
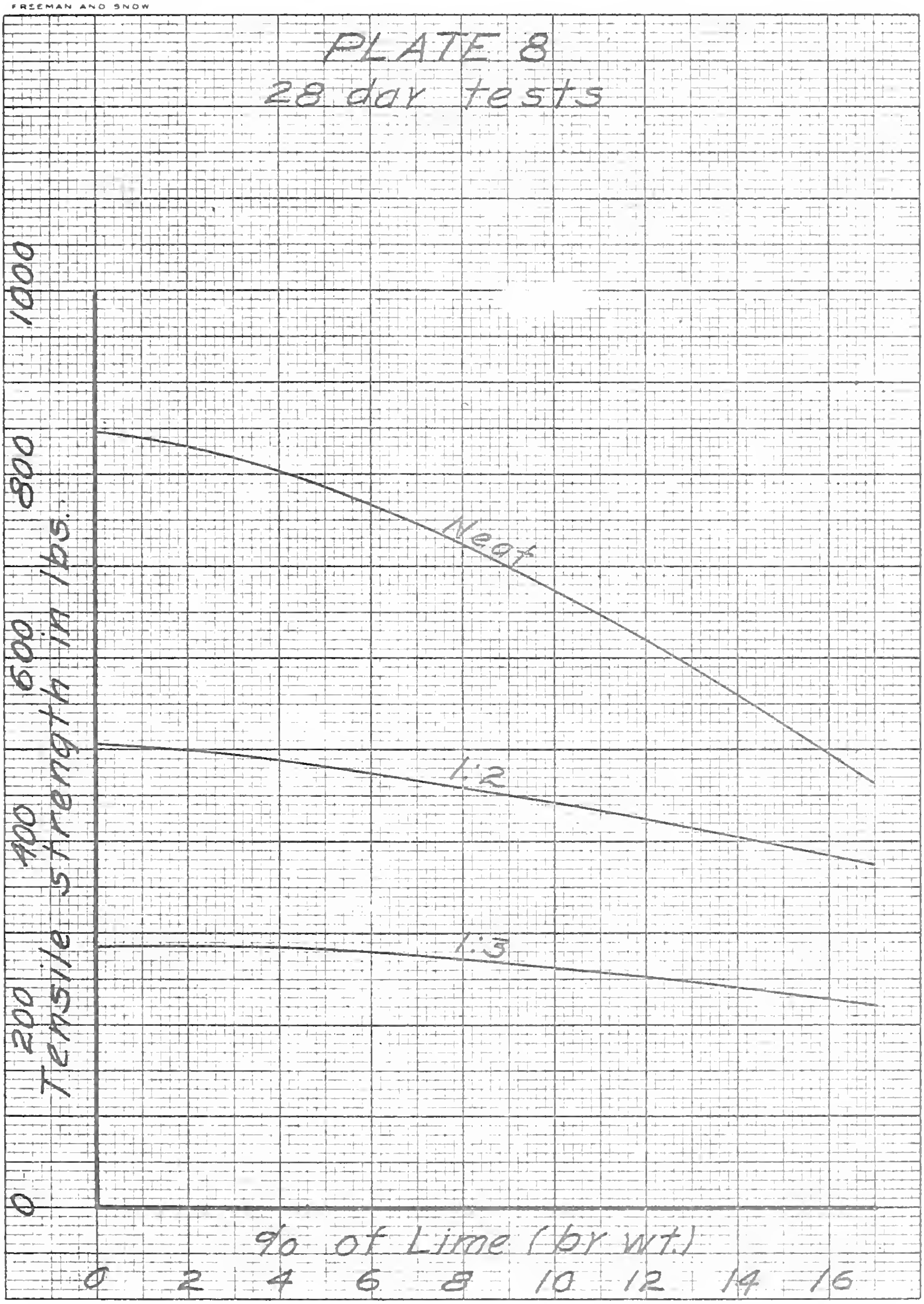


PLATE 7
7 day tests
Neat
1:2
1:3
Tensile strength in lbs.
0
200
400
600
800
% of Lime (by wt.)
0
2
4
6
8
10
12
14
16


FREEMAN AND SNOW
PLATE 8
28 day tests
Tensile strength in lbs.
1000
800
600
400
200
0
Neat
1:2
1:3
% of Lime (by wt.)
0
2
4
6
8
10
12
14
16

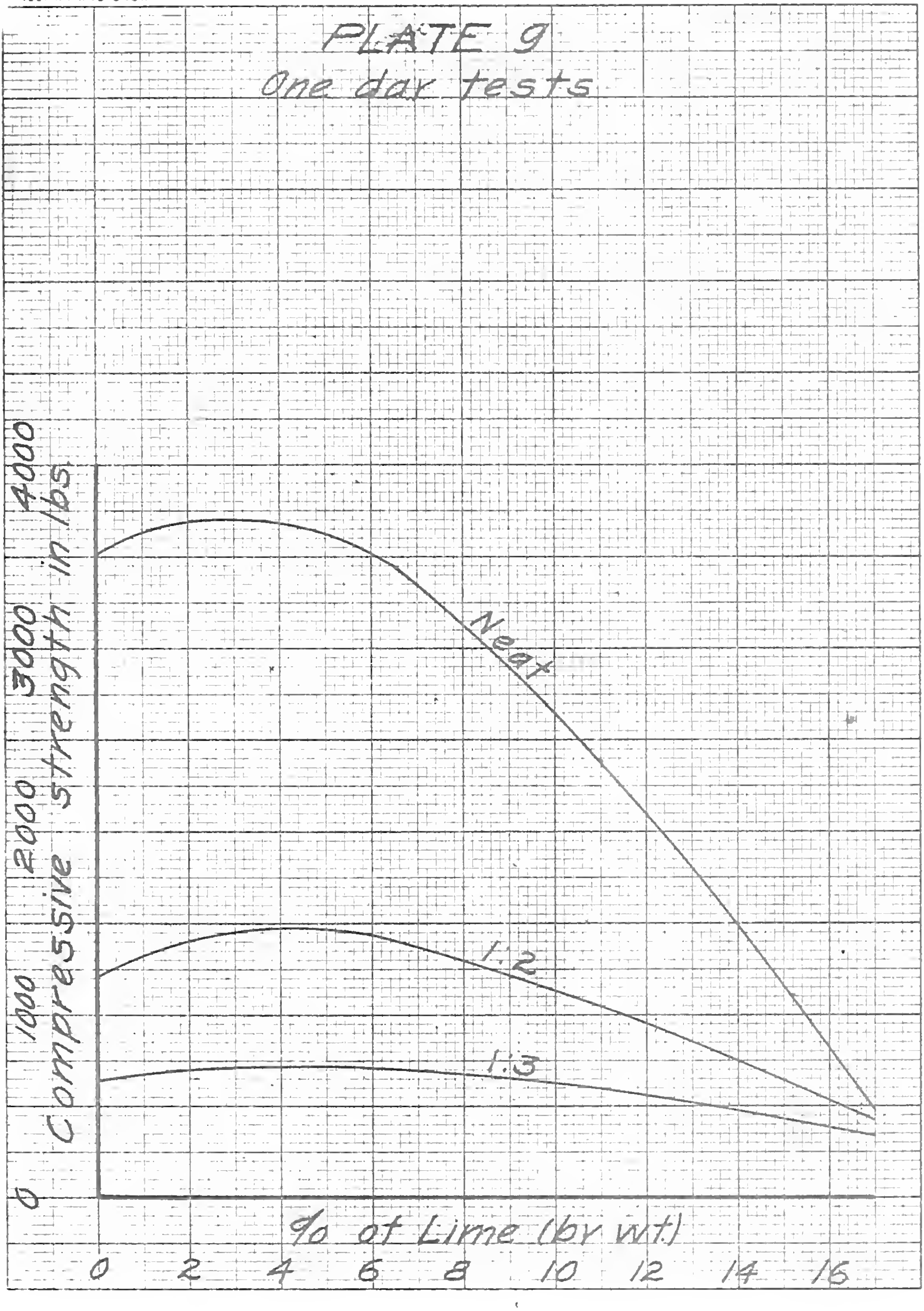
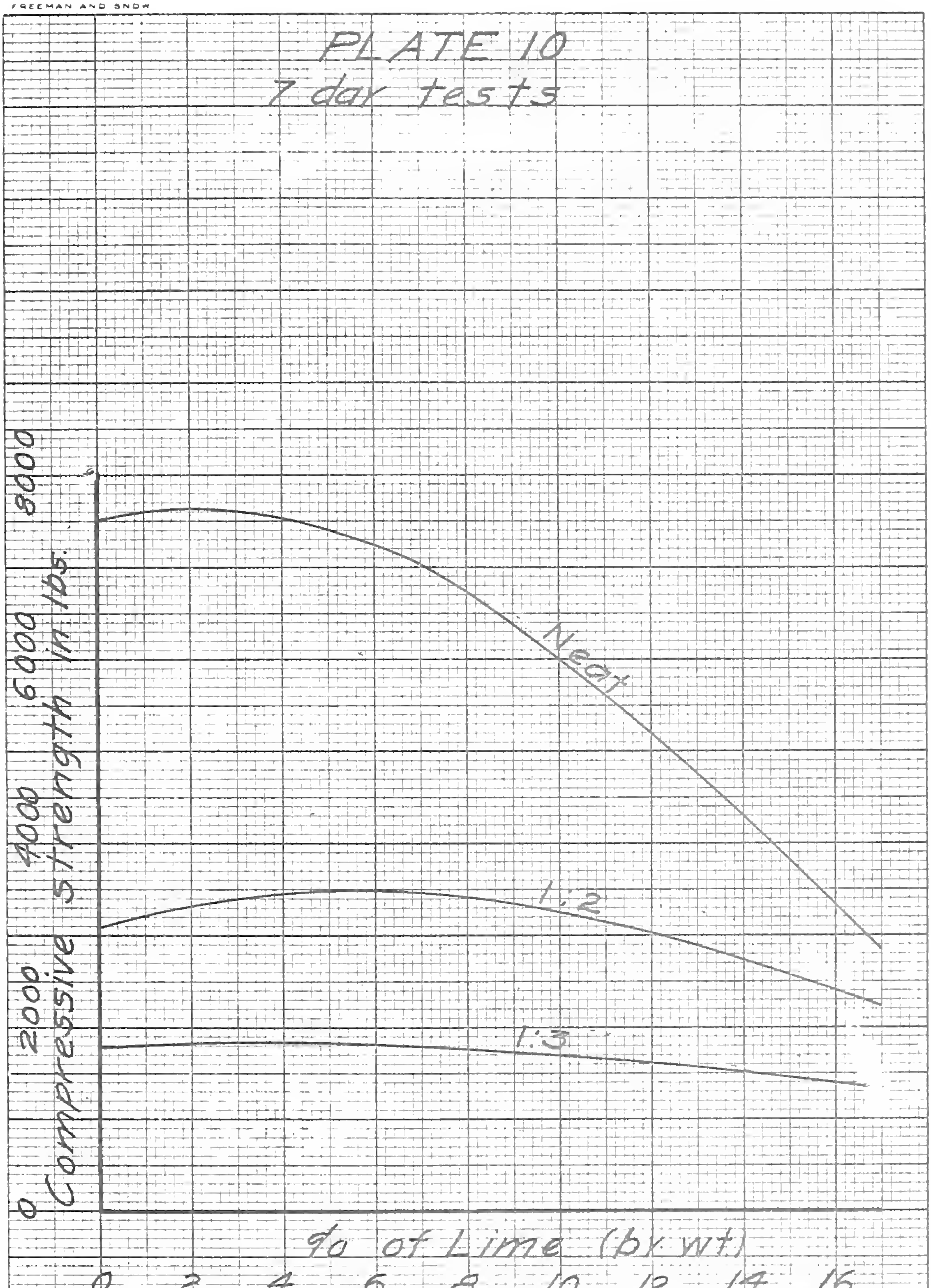
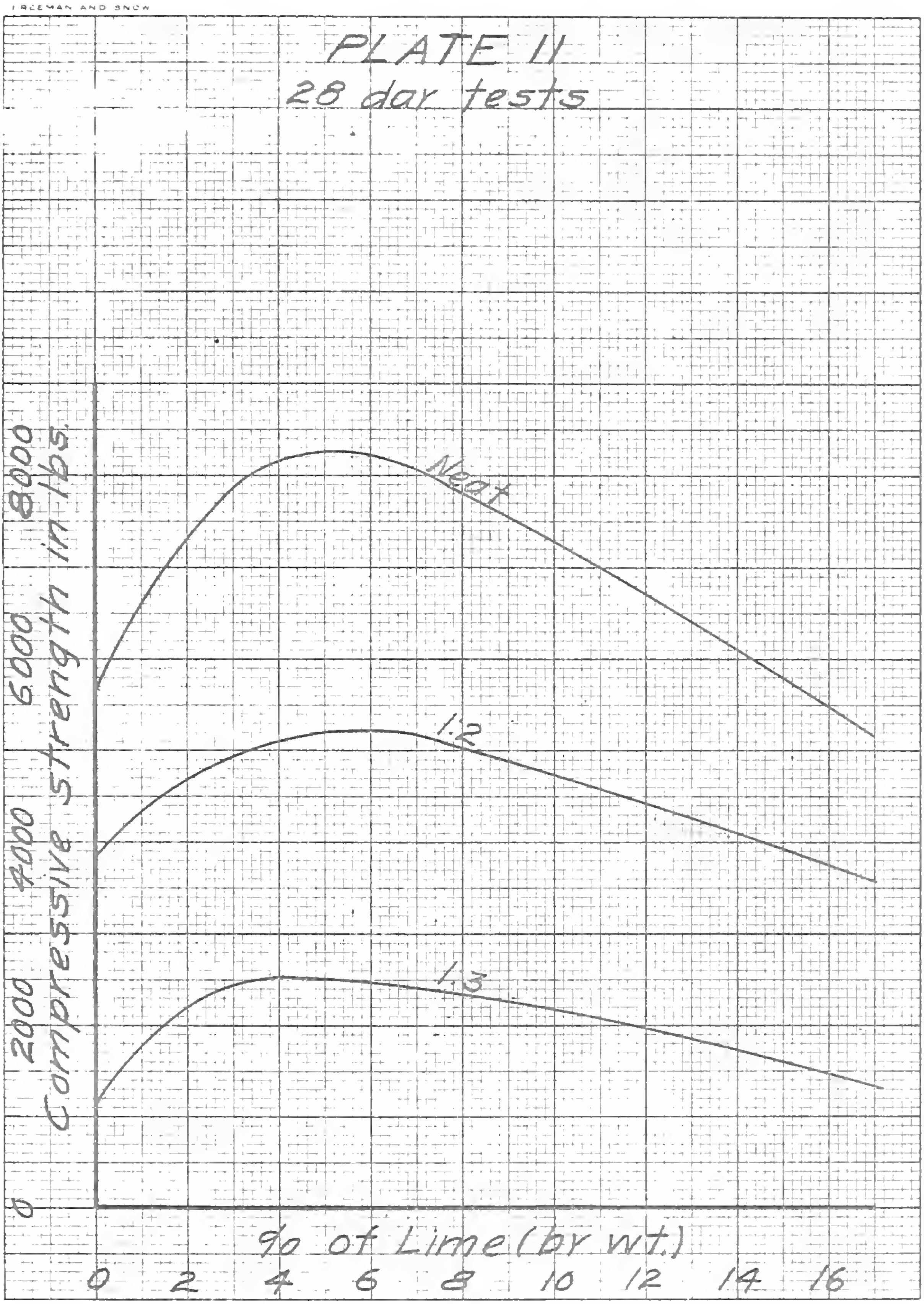
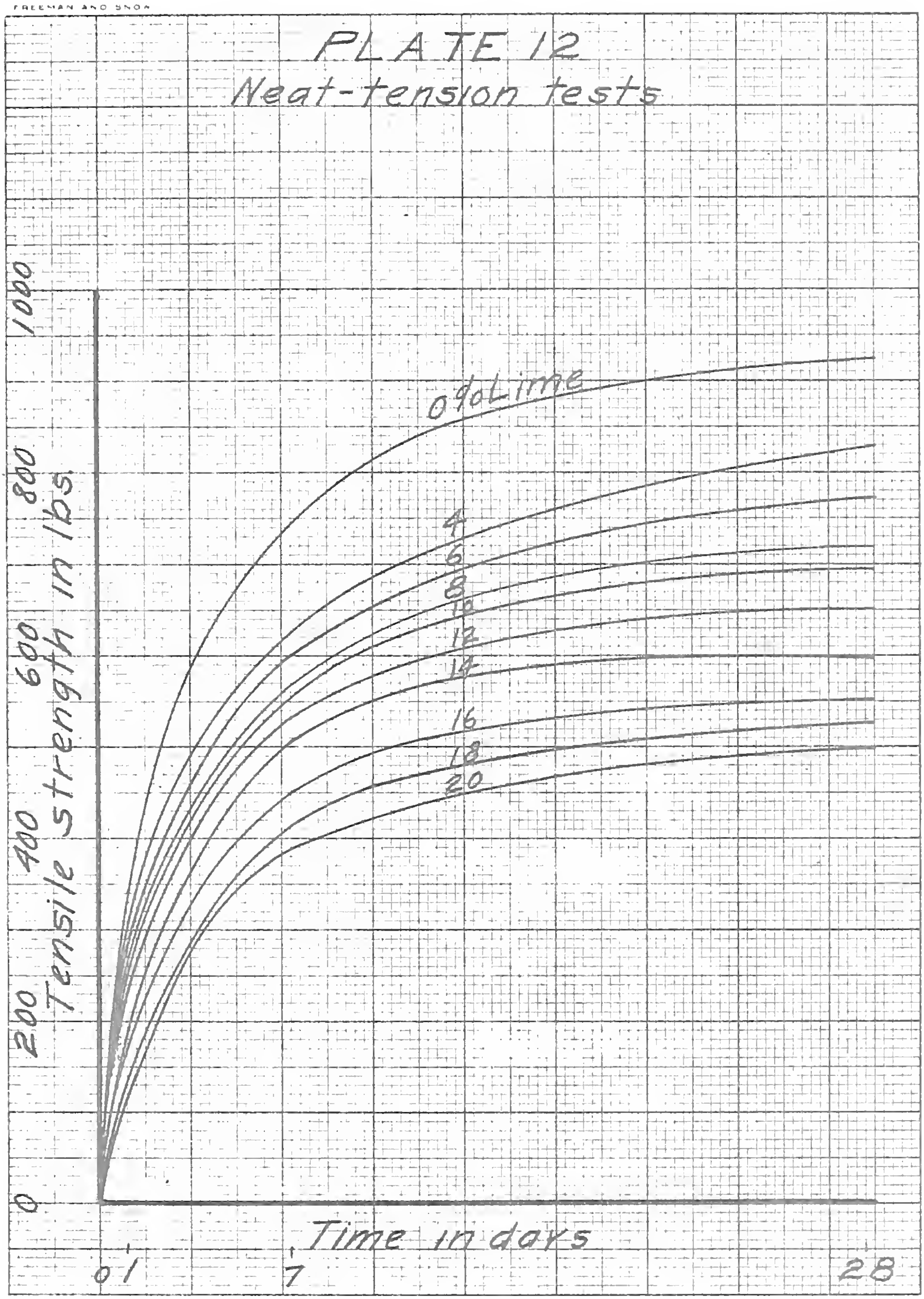


PLATE 9
One day tests
Compressive strength in lbs
0
1000
2000
3000
4000
Neat
1:2
1:3
% of Lime (by wt)
0
2
4
6
8
10
12
14
16


FREEMAN AND SNOW
PLATE 10
7 day tests
Compressive strength in lbs.
0
2000
4000
6000
8000
Neat
1:2
1:3
% of Lime (by wt)
0
2
4
6
8
10
12
14
16


FREEMAN AND SNOW
PLATE II
28 day tests
Compressive strength in lbs.
0
2000
4000
6000
8000
Neat
1:2
1:3
% of Lime (by wt.)
0
2
4
6
8
10
12
14
16


FREEMAN AND SNOW
PLATE 12
Neat-tension tests
0% Lime
4
6
8
10
12
14
16
18
20
Tensile strength in lbs
0
200
400
600
800
1000
Time in days
0
1
7
28

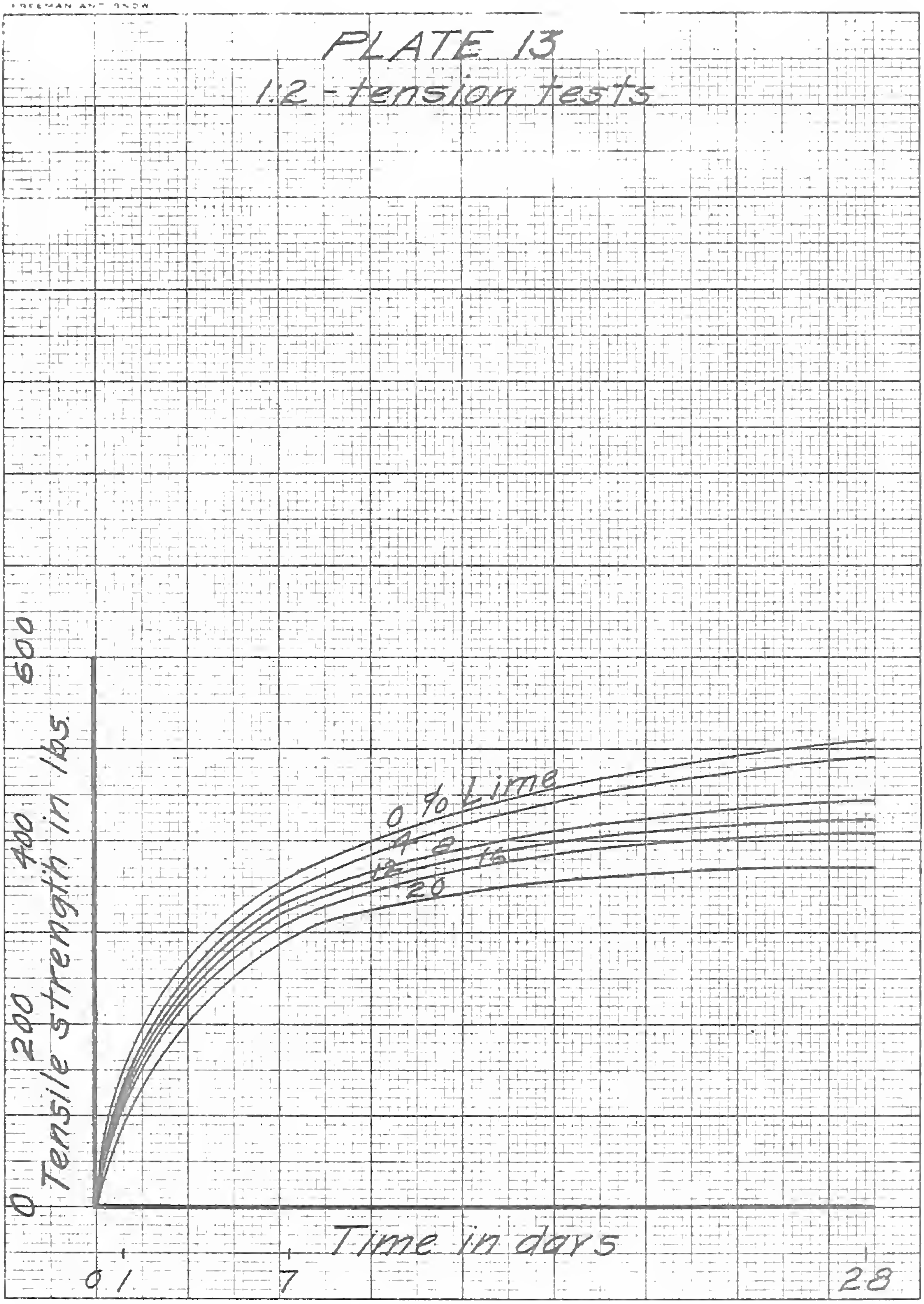
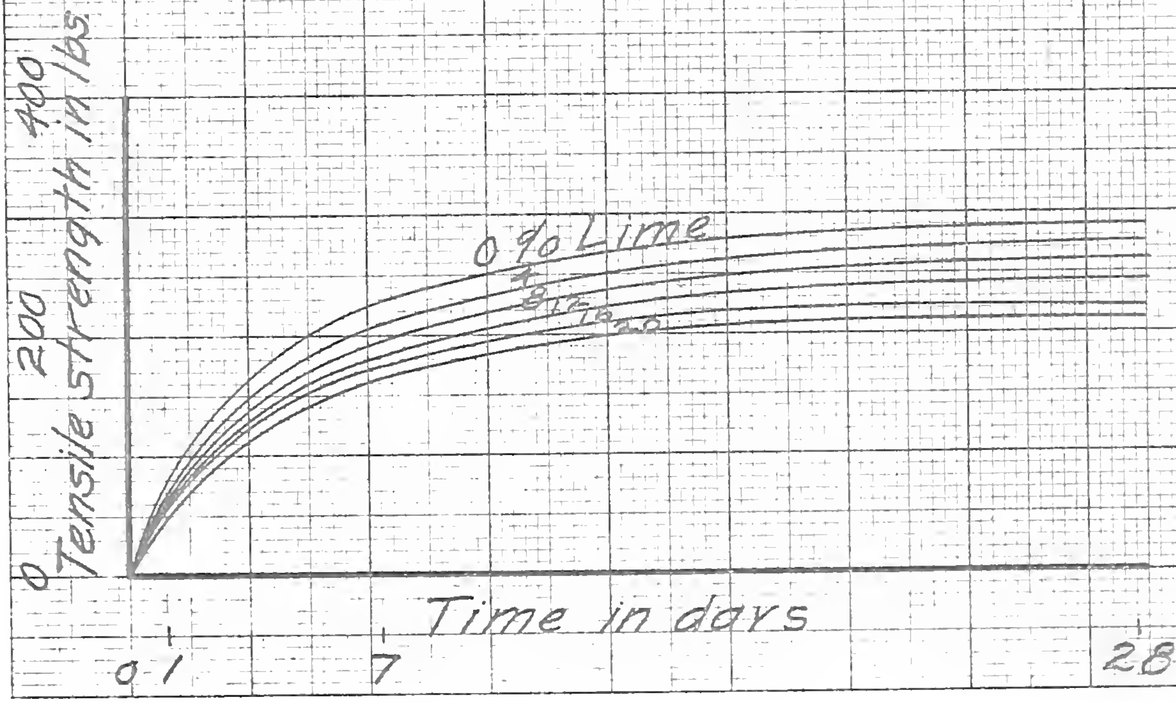


PLATE 13
1:2 - tension tests
Tensile strength in lbs.
0
200
400
600
0 % Lime
4
8
12
16
20
Time in days
0
1
7
28

FREEMAN AND SNOW

PLATE 14

1:3- tension tests



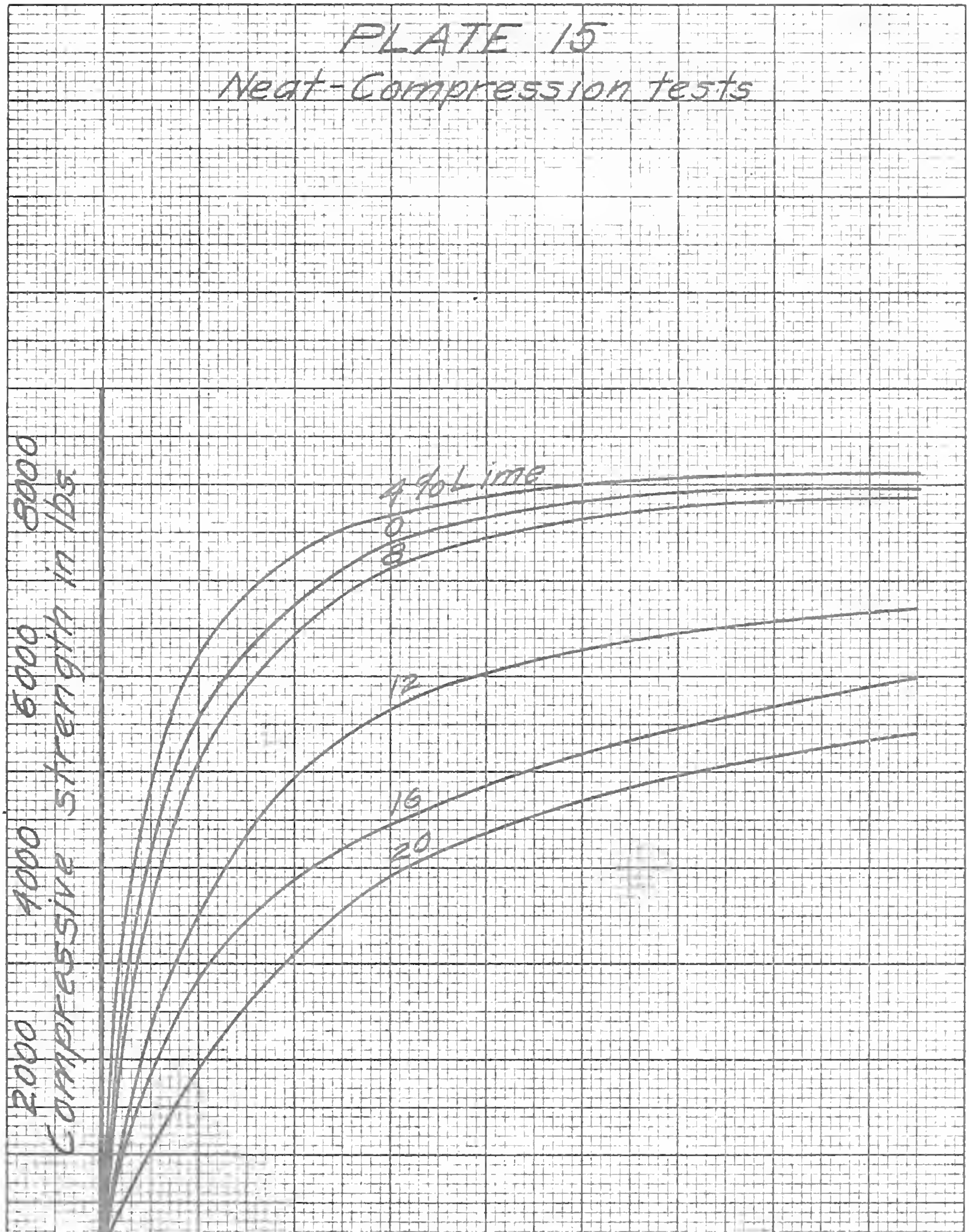
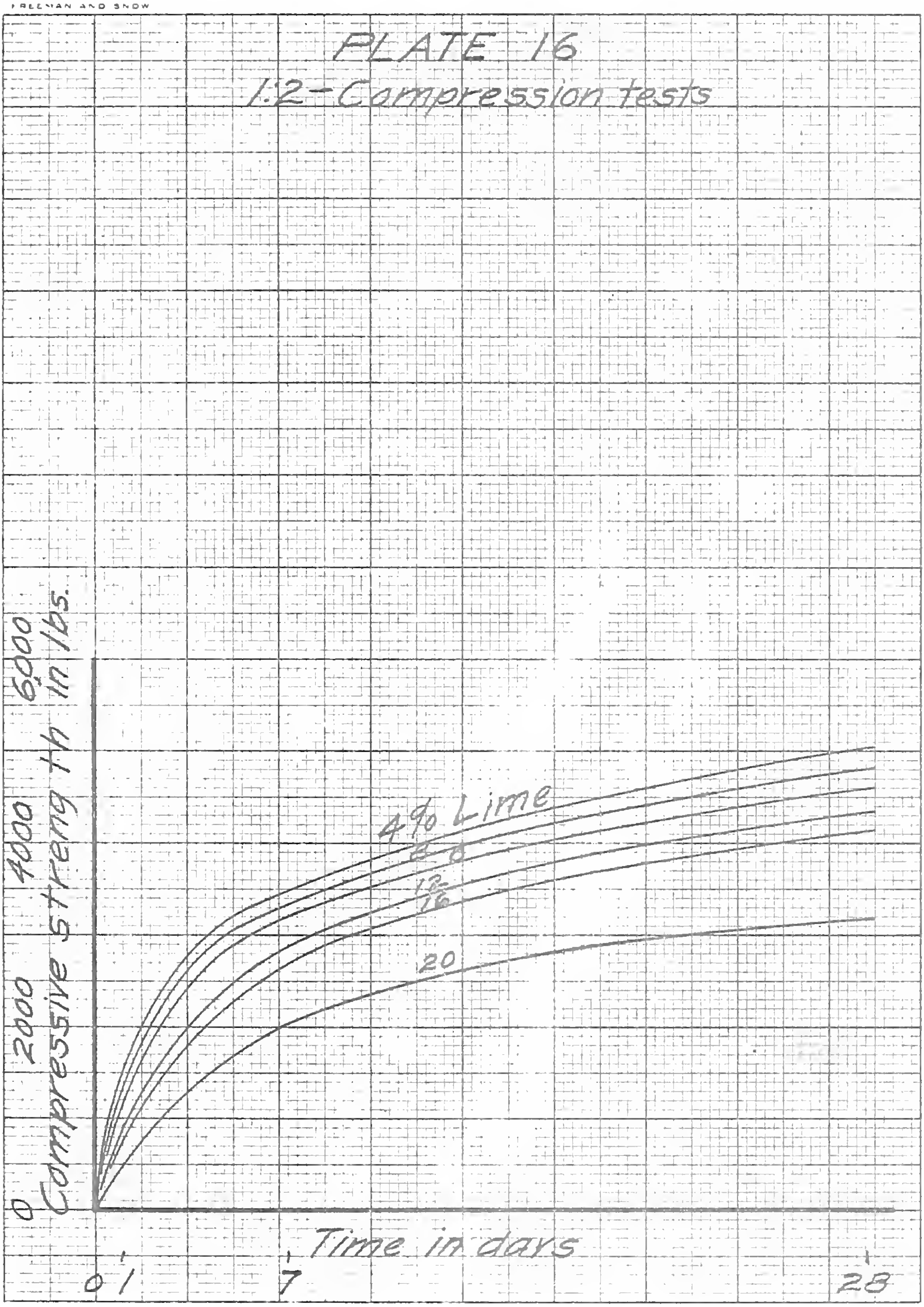
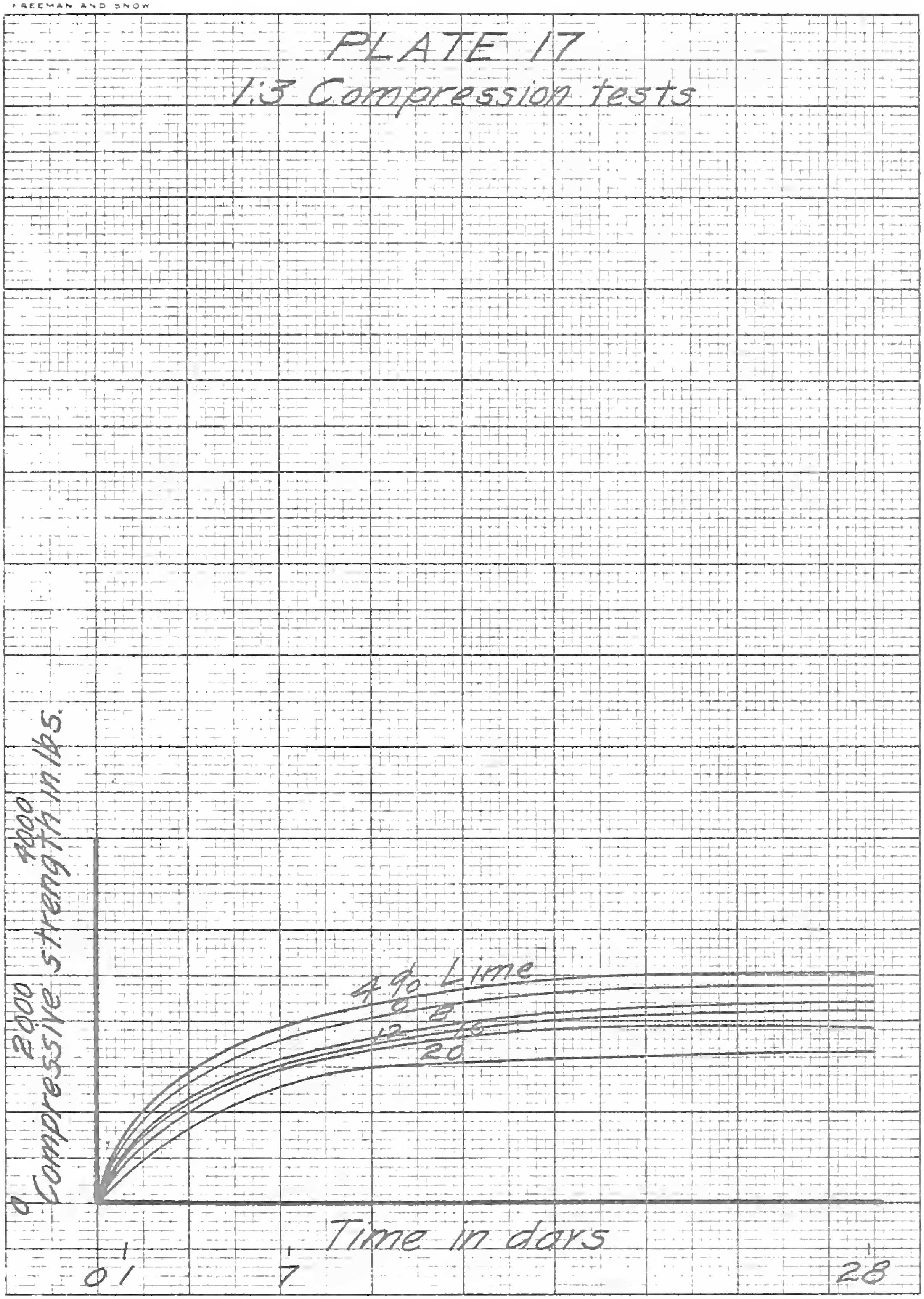


PLATE 15
Neat-Compression tests
Compressive strength in lbs.
0
2000
4000
6000
8000
4% Lime
0
8
12
16
20
Time in days
0
1
7
28


FREEMAN AND SNOW
PLATE 16
1:2 - Compression tests
Compressive strength in lbs.
0
2000
4000
6000
4% Lime
8
12
16
20
Time in days
0
1
7
28


FREEMAN AND SNOW
PLATE 17
1:3 Compression tests
Compressive strength in lbs.
0
2000
4000
4% Lime
0
8
12
16
20
Time in days
0
1
7
28

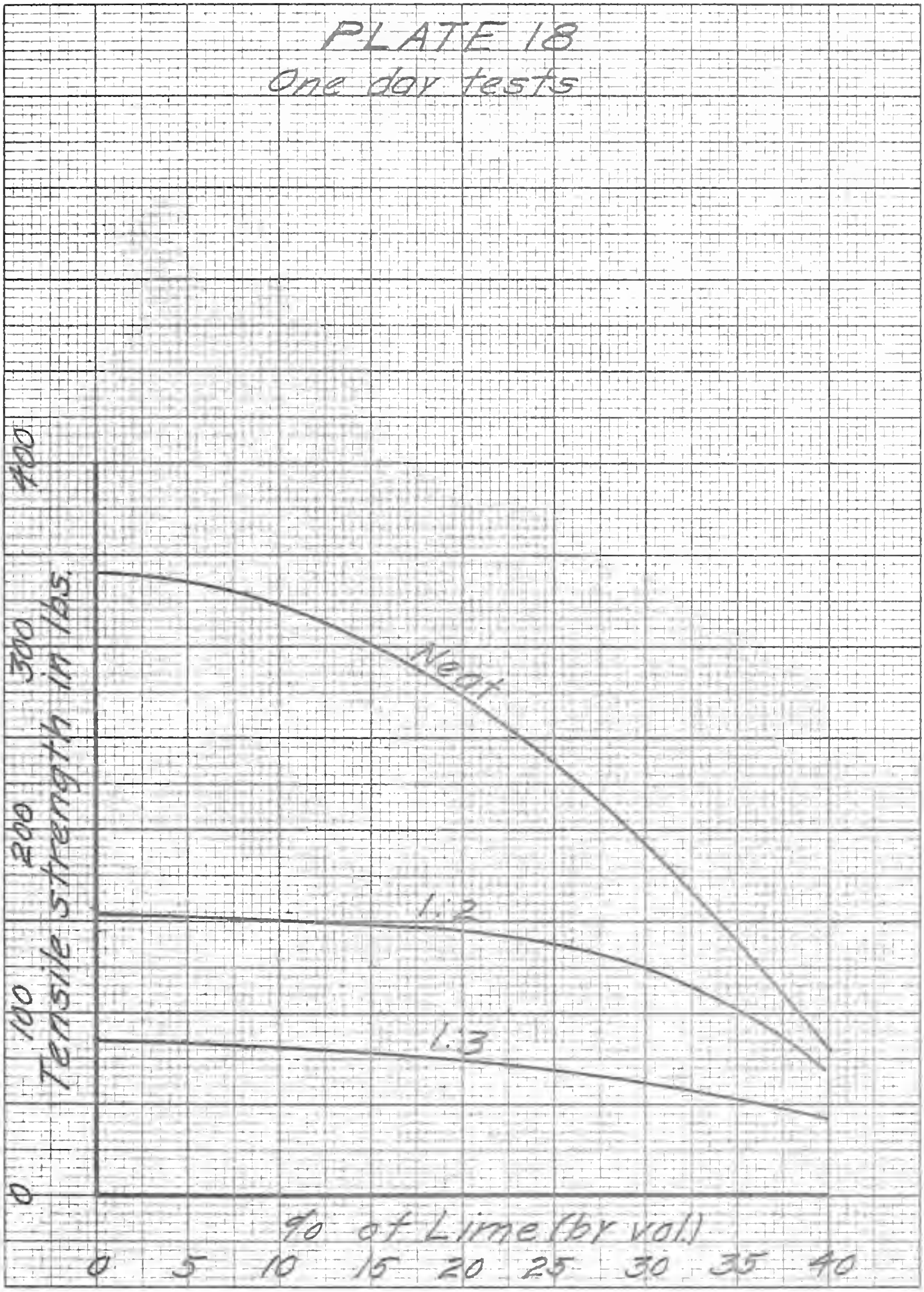
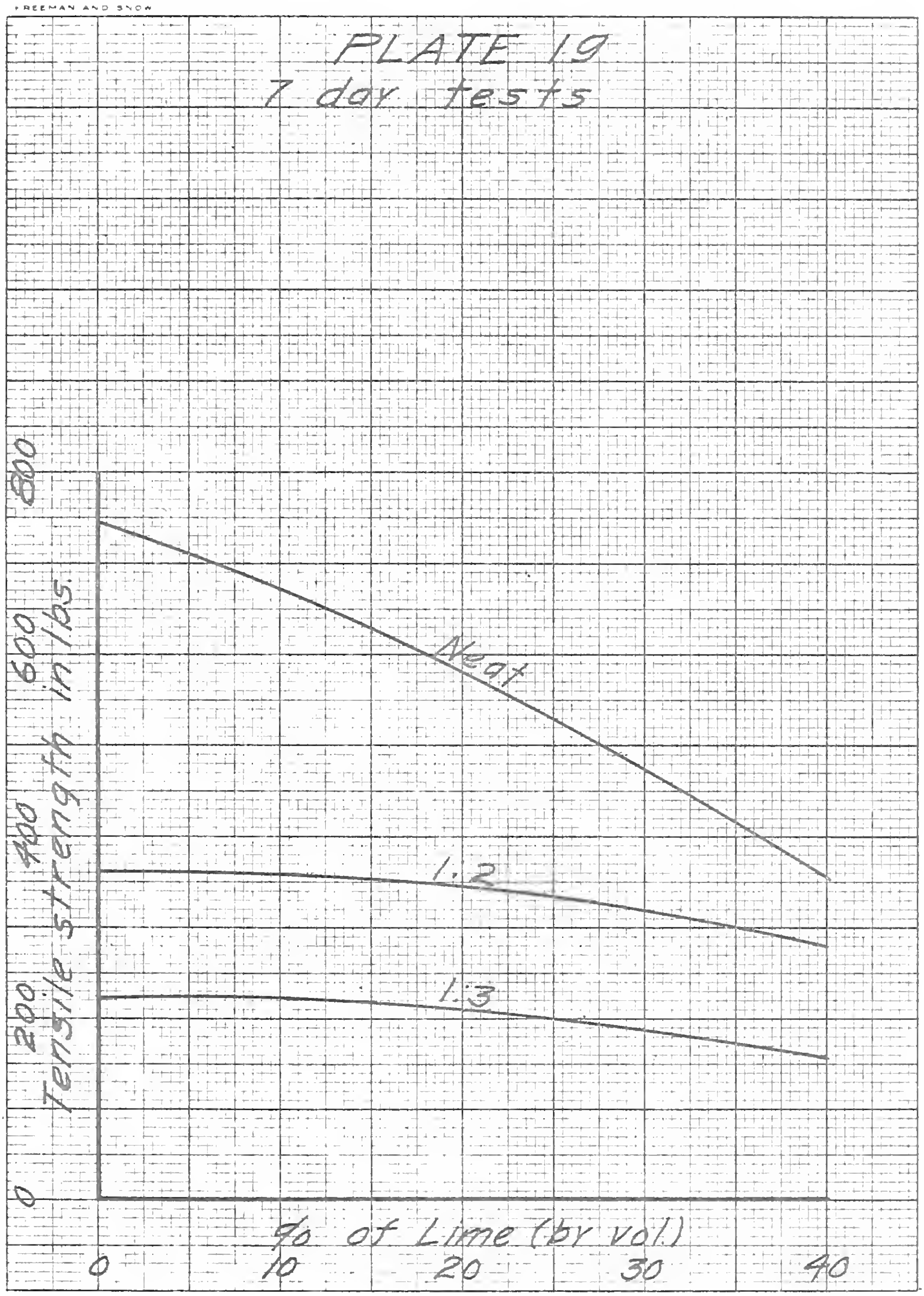
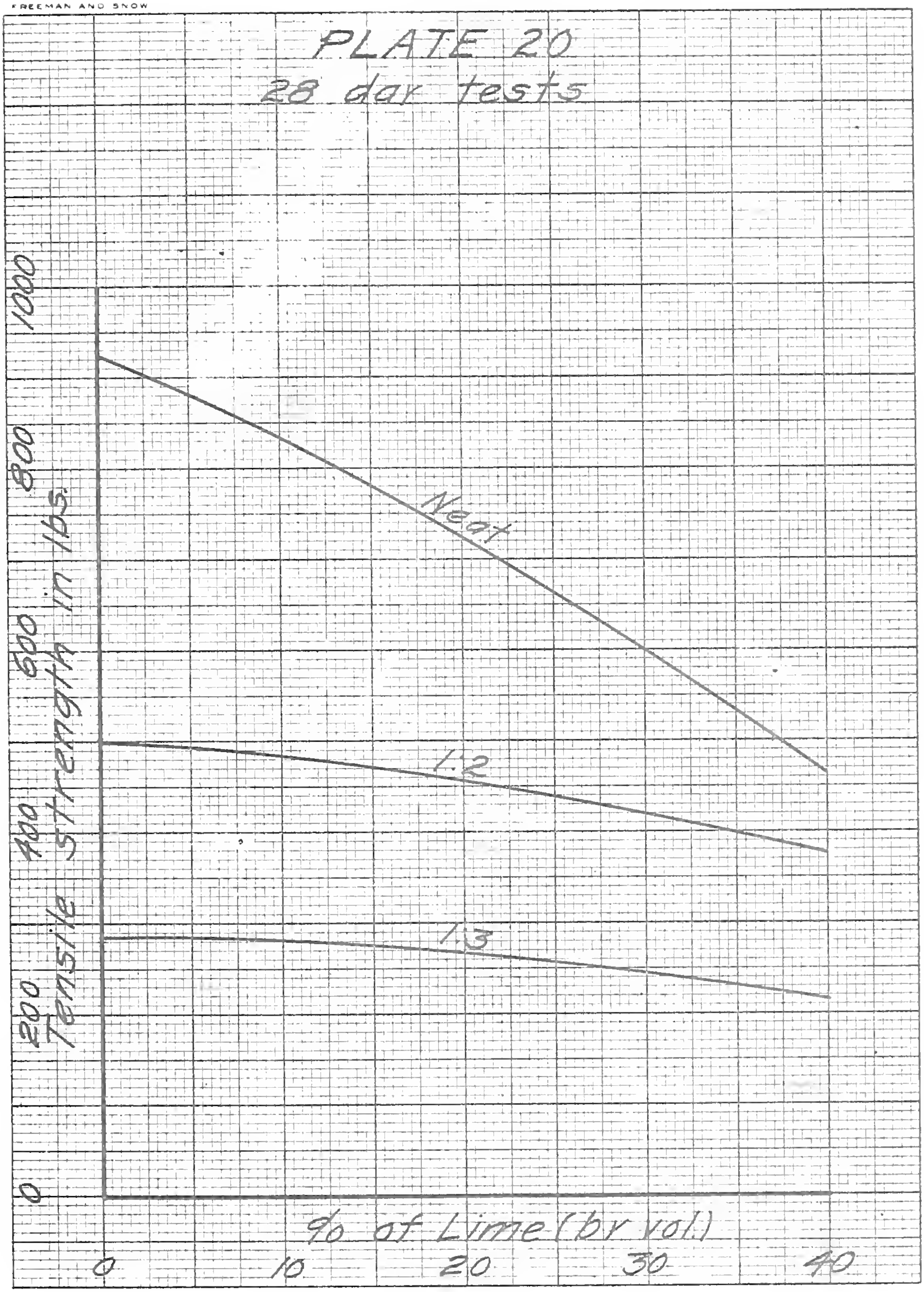
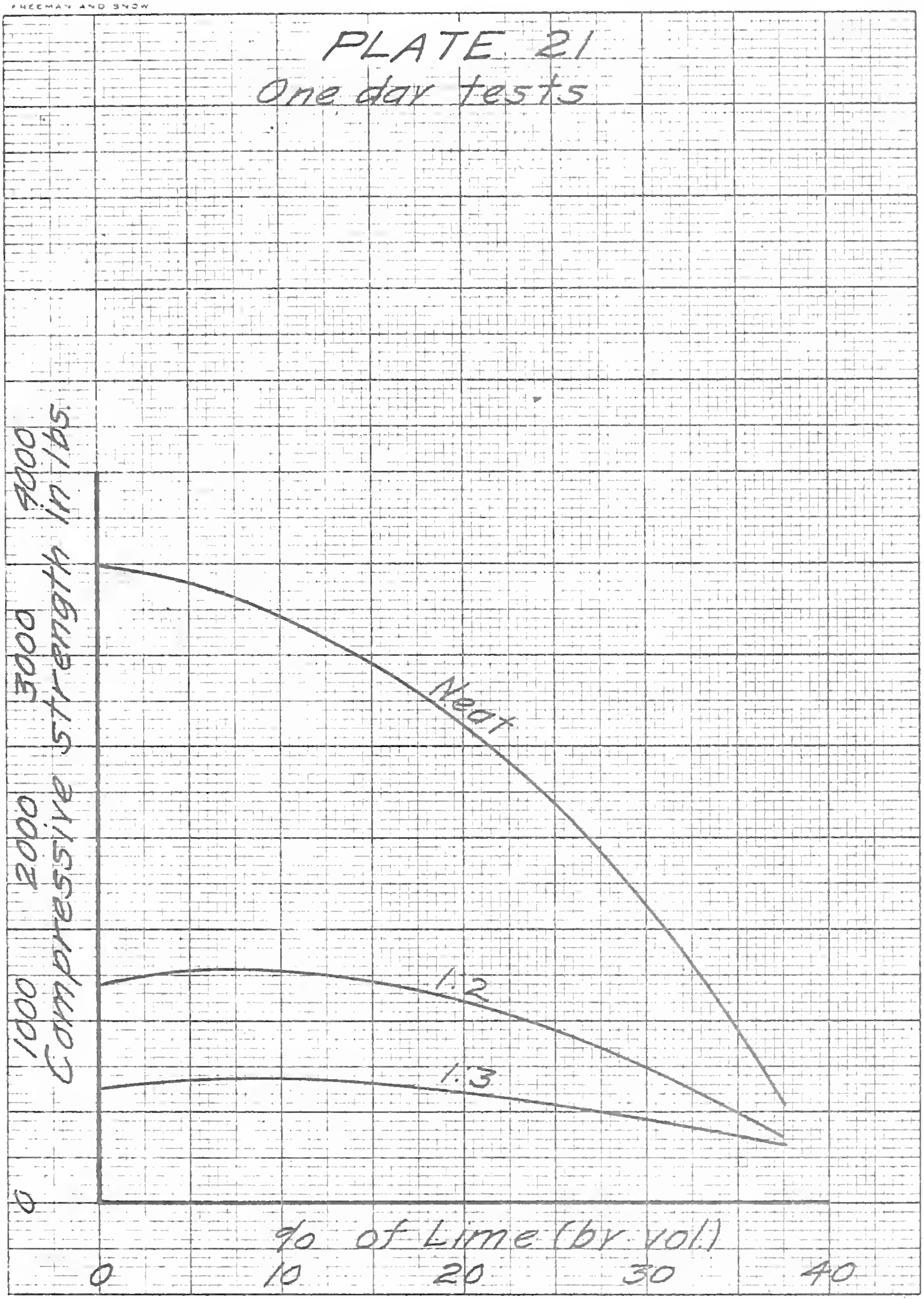


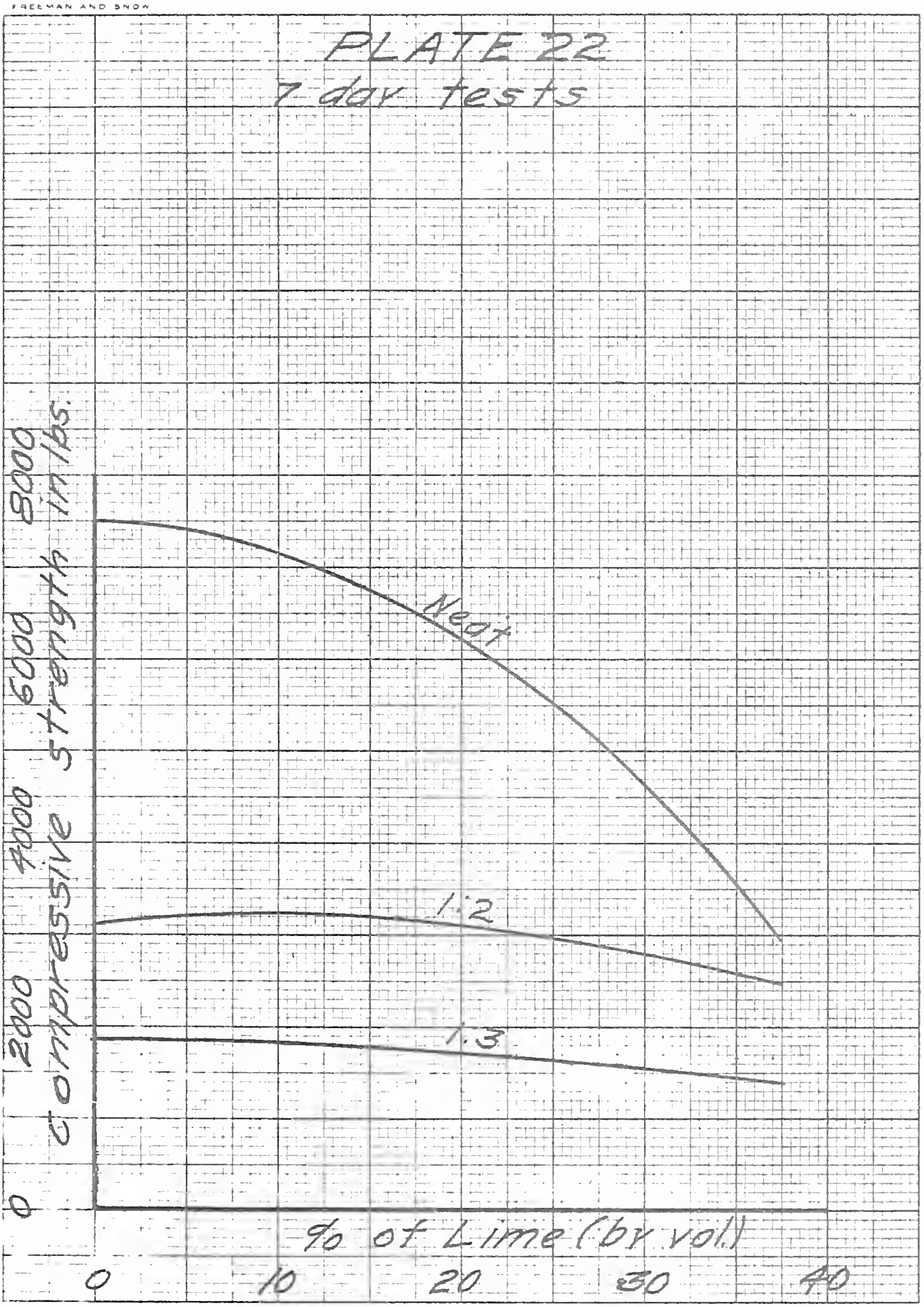
PLATE 18
One day tests
Tensile strength in lbs.
0
100
200
300
400
Neat
1:2
1:3
% of Lime (by vol.)
0
5
10
15
20
25
30
35
40

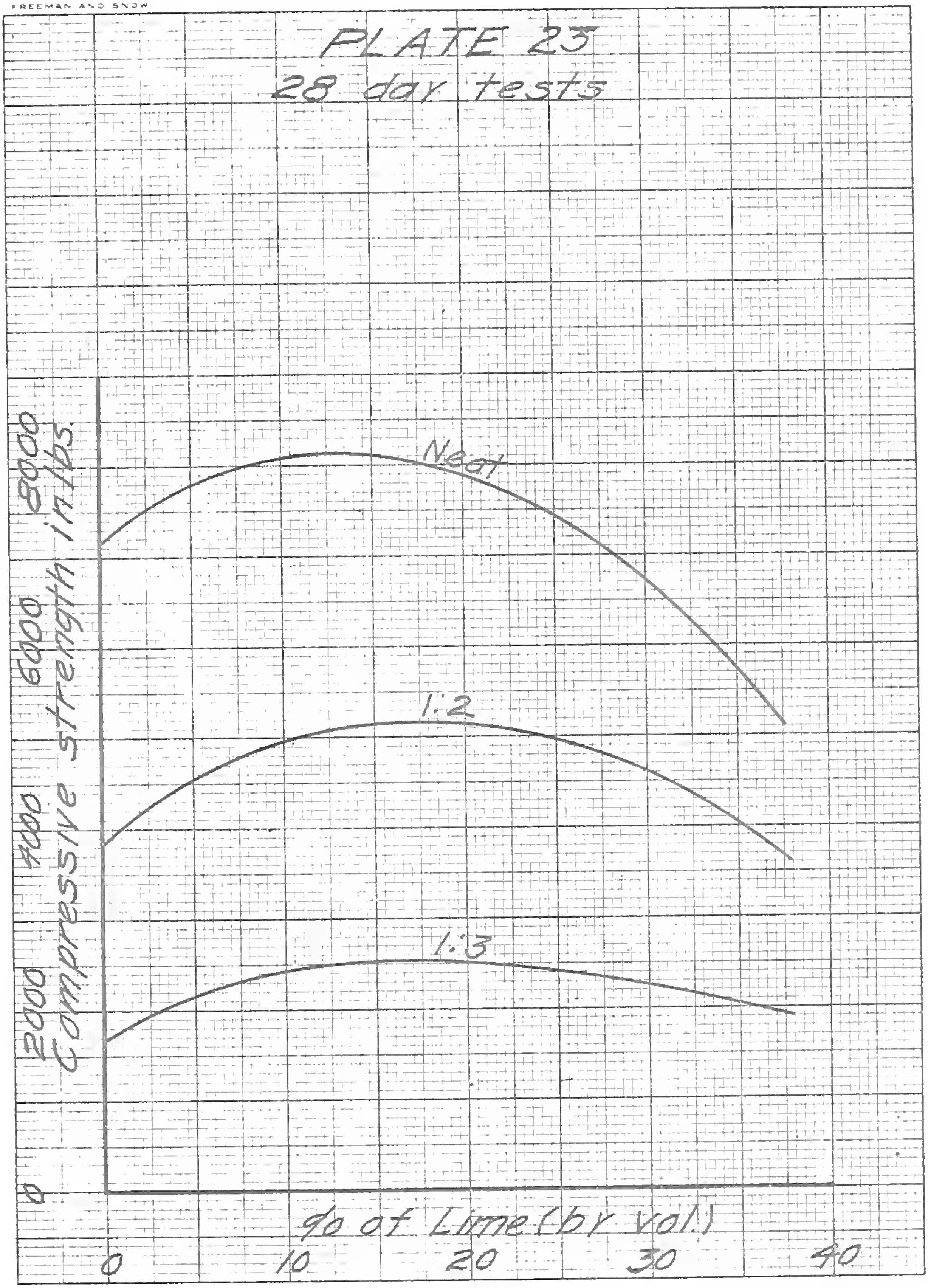

FREEMAN AND SNOW
PLATE 19
7 day tests
Tensile strength in lbs
800
600
400
200
0
Neat
1:2
1:3
% of Lime (by vol)
0
10
20
30
40

FREEMAN AND SNOW




FREEMAN AND SNOW
PLATE 21
One day tests
Compressive strength in lbs.
0
1000
2000
3000
4000
Neat
1:2
1:3
% of Lime (by vol.)
0
10
20
30
40


FREEMAN AND SNOW
PLATE 22
7 day tests
Compressive strength in lbs.
0
2000
4000
6000
8000
Neat
1:2
1:3
% of Lime (by vol.)
0
10
20
30
40


FREEMAN AND SNOW
PLATE 23
28 day tests
Neat
1:2
1:3
Compressive strength in lbs
0
2000
4000
6000
8000
% of Lime (by vol.)
0
10
20
30
40

PART 2

LABORATORY DATA

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste — MIX A — 0 % Lime

Normal Consistency 24 % — Mixed February 3, 1915

Time of Set: Initial $\frac{3-15}{60}$ hrs. Final: $\frac{4-15}{60}$ hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	12:30	2/4/15	1:15	H	350				
2					271	341			
3					402				
4				K			3402		
5							3495	3511	
6							3620		
7		2/10/15		H	763				
8					684	745			
9					788				
10				K			5925		
11							7978	7488	
12							8562		
13		3/3/15		H	956				
14					Flaw	923			
15					891				
16				K			5715		
17							5440	5660	
18							5820		
19		5/11/15		H	860				
20					834	824			
21					789				
22				K			9500		
23							11080	9617	
24							8270		
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste — MIX K — 4 % Lime

Normal Consistency 26½ % — Mixed March 24, 1915

Time of Set: Initial $\frac{3-15}{60}$ hrs. Final: $\frac{4-25}{60}$ hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	11:00	3/25/15	1:	H	305				
2					279	280			
3					256				
4				K			2960		
5							2760	2890	
6							2950		
7		3/31/15		H	560				
8					687	599			
9					549				
10				K			7850		
11							6560	7337	
12							7600		
13		4/21/15		H	830				
14					860	836			
15					817				
16				K			8000		
17							8260	8130	
18							Flaw		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste — MIX J — 6 % Lime

Normal Consistency 26½ % — Mixed March 24, 1915

Time of Set: Initial 3-10/60 hrs. Final: 4-30/60 hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:15	3/25/15	1:	H	250				
2					380	271			
3					284				
4				K			4080		
5							3750	3915	
6							Flaw		
7		3/31/15		H	621				
8					500	624			
9					750				
10				K			7130		
11							4380	6073	
12							6710		
13		4/21/15		H	750				
14					824	772			
15					743				
16				K			8920		
17							7500	8193	
18							8170		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste — MIX H — 8 % Lime

Normal Consistency 27- % — Mixed March 19, 1915

Time of Set: Initial 3-10/60 hrs. Final: 4-30/60 hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	3/20/15	11	H	350				
2					333	331			
3					311				
4				K			2720		
5							2970	2730	
6							2500		
7		3/26/15		H	539				
8					552	530			
9					500				
10				K			8170		
11							7520	8127	
12							8690		
13		4/16/15		H	544				
14					540	529			
15					502				
16				K			8130		
17							8040	8085	
18							Flaw		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste　　　MIX B　　　10 % Lime

Normal Consistency 27 %　　　Mixed February 8, 1915

Time of Set: Initial $\frac{3\text{-}15}{60}$ hrs. Final: $\frac{4\text{-}35}{60}$ hrs.

No	Hr. Mixed	Tested			Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	Average	
1	10:30	2/9/15	1:	H	262				
2			15		261	252			
3					234				
4				K			1980		
5							1650	1830	
6							1860		
7		2/15/15		H	524				
8					585	554			
9					554				
10				K			6647		
11							7538	6475	
12							5240		
13		3/8/15		H	691				
14					723	695			
15					672				
16				K			10200		
17							5980	7155	
18							5286		
19		5/11/15		H	709				
20					625	656			
21					634				
22				K			5530		
23							5160	5345	
24							Flaw		
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste — MIX C — 12 % Lime

Normal Consistency 30 % — Mixed February 10, 1915

Time of Set: Initial $\frac{3-25}{60}$ hrs. Final: $\frac{4-45}{60}$ hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	11:00	2/11/15	1:	H	254				
2			15		255	254			
3					Flaw				
4				K			1160		
5							1540	1513	
6							1840		
7		2/17/15		H	540				
8					615	543			
9					474				
10				K			6040		
11							4425	4905	
12							4250		
13		3/10/15		H	658				
14					676	640			
15					614				
16				K			4670		
17							7780	6730	
18							7740		
19		5/11/15		H	680				
20					624	622			
21					563				
22				K			9260		
23							5300	8230	
24							10140		
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste MIX D 14 % Lime

Normal Consistency 31 % Mixed February 10 1915

Time of Set: Initial 3-30/60 hrs. Final: 5 hrs.

No	Hr. Mixed	Tested Date	Hr.	By	Tensile Stress Briquette	Average	Comp. Stress Cube	Average	Remarks
1	3:00	2/11/15	1:	H	190				
2					213	201			
3					200				
4				K			980		
5							840	937	
6							990		
7		2/17/15		H	486				
8					559	510			
9					485				
10				K			4968		
11							4800	4927	
12							5012		
13		3/10/15		H	591				
14					687	595			
15					507				
16				K			6110		
17							7620	6650	
18							6220		
19		5/11/15		H	618				
20					533	586			
21					606				
22				K			10330		
23							9630	9090	
24							7310		
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste MIX E 16 % Lime

Normal Consistency 33 % Mixed February 15, 1915

Time of Set: Initial $\frac{3-35}{60}$ hrs. Final: $\frac{5-15}{60}$ hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	10:30	2/16/15	1:	H	175				
2					197	182			
3					173				
4				K			1672		
5							1170	1547	
6							1800		
7		2/23/15		H	469				
8					414	449			
9					464				
10				K			3805		
11							3825	3877	
12							4000		
13		3/15/15		H	496				
14					555	543			
15					578				
16				K			3860		
17							4850	4390	
18							4460		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	OK
2	Normal in water	OK
3	Accelerated	OK

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste — MIX F — 18 % Lime

Normal Consistency 34 % — Mixed February 17, 1915

Time of Set: Initial 4 hrs. Final: 5-30/60 hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	2/18/15	1:	H	139				
2					152	136			
3					117				
4				K			Flaw		
5							1295	1107	
6							920		
7		2/24/15		H	435				
8					403	414			
9					404				
10				K			3070		
11							4525	3785	
12							3760		
13		3/17/15		H	621				
14					609	596			
15					560				
16				K			5965		
17							6390	5792	
18							5020		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	Cracks within twenty four hours
2	Normal in water	" " " " "
3	Accelerated	" " " " "

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

Neat Cement Paste MIX G 20 % Lime

Normal Consistency 36 % Mixed February 17 1915

Time of Set: Initial 4-30/60 hrs. Final: 6 hrs.

No	Hr. Mixed	Tested Date	Hr.	By	Tensile Stress Briquette	Average	Comp. Stress Cube	Average	Remarks
1	2:00	2/18/15	1:	H	108				
2					115	117			
3					128				
4				K			645		
5							570	608	
6							610		
7		2/24/15		H	428				
8					380	391			
9					364				
10				K			3580		
11							2560	2980	
12							2800		
13		3/17/15		H	479				
14					521	498			
15					495				
16				K			5250		
17							5720	5473	
18							5450		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	Cracks within twenty four hours
2	Normal in water	" " " " "
3	Accelerated	" " " " "

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar — MIX A1 — 0 % Lime

Normal Consistency $12\frac{1}{2}$ % — Mixed February 24, 1915

Time of Set: Initial — hrs. Final: — hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	2/25/15	1:	H	140				
2					152	147			
3					149				
4				K			1360		
5							1120	1207	
6							1140		
7		3/3/15		H	344				
8					356	363			
9					390				
10				K			1910		
11							1690	1720	
12							1560		
13		3/24/15		H	495				
14					527	504			
15					490				
16				K			3710		
17							3540	3880	
18							4390		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar   MIX K1   4 % Lime

Normal Consistency 11.9 %   Mixed March 29, 1915

Time of Set: Initial ____ hrs. Final: ____ hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	10:30	3/30/15	11	H	151				
2					143	156			
3					175				
4				K			1460		
5							1360	1480	
6							1620		
7		4/6/15		H	453				
8					383	404			Eight day
9					375				test
10				K			3530		Eight day
11							3250		test
12							3500		
13		4/26/15		H	482				
14					490	493			
15					507				
16				K			4450		
17							5080	4943	
18							5300		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar MIX J1 6 % Lime

Normal Consistency 11.9 % Mixed March 26, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	10:30	3/27/15	11	H	146				
2					105	127			
3					130				
4				K			720		
5							800	750	
6							730		
7		4/3/15		H	322				
8					300	311			Eight day
9					Flaw				test
10				K			2350		
11							2380	2453	Eight day
12							2630		test
13		4/23/15		H	371				
14					370	324			
15					232				
16				K			4160		
17							2820	3250	
18							2770		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar — MIX H1 — 8 % Lime

Normal Consistency 12 % — Mixed March 26, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:00	3/27/15	11	H	164				
2					157	160			
3					Flaw				
4				K			840		
5							1020	930	
6							Flaw		
7		4/3/15		H	377				
8					412	410			Eight day
9					440				test
10				K			3010		
11							2460	2877	Eight day
12							3160		test
13		4/23/15		H	440				
14					413	429			
15					433				
16				K			3270		
17							2760	3015	
18							Flaw		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA
MIX B1

1:2 Cement Mortar — 10 % Lime

Normal Consistency 14 % — Mixed February 24, 1915

Time of Set: Initial — hrs. Final: — hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	12:45	2/25/15	1:	H	95				
2					107	102			
3					105				
4				K			740		
5							640	733	
6							820		
7		3/3/15		H	313				
8					286	300			
9					300				
10				K			2705		
11							2350	2405	
12							2160		
13		3/24/15		H	427				
14					470	439			
15					421				
16				K			5610		
17							5070	5320	
18							5280		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar — MIX C1 — 12 % Lime

Normal Consistency 12½ % — Mixed February 26, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	10:30	2/27/15	11	H	144				
2					146	143			
3					139				
4				K			730		
5							740	733	
6							730		
7		3/8/15		H	410				
8					460	418			Ten day
9					385				test
10				K			2620		
11							3545	3155	Ten day
12							3300		test
13		3/26/15		H	368				
14					436	409			
15					425				
16				K			5890		
17							5540	5543	
18							5200		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar　　　MIX D1　　　14 % Lime

Normal Consistency 13.8 %　　　Mixed March 1, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	3/2/15	1:	H	130				
2					176	153			
3					134				
4				K			870		
5							1020	983	
6							1060		
7		3/8/15		H	335				
8					336	327			
9					312				
10				K			3040		
11							3288	3309	
12							3600		
13		3/29/15		H	505				
14					392	451			
15					456				
16				K			3960		
17							5050	4253	
18							3750		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar — MIX E1 — 16 % Lime

Normal Consistency 14.3 % — Mixed March 3, 1915

Time of Set: Initial ——— hrs. Final: ——— hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	3/4/15	1:	H	130				
2					120	123			
3					120				
4				K			710		
5							810	757	
6							750		
7		3/10/15		H	304				
8					334	319			
9					319				
10				K			3460		
11							3120	3183	
12							2970		
13		3/31/15		H	383				
14					422	413			
15					432				
16				K			3620		
17							4540	4090	
18							4110		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar MIX F1 18 % Lime

Normal Consistency 14.5 % Mixed March 3, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	12:15	3/4/15	1:	H	126				
2					100	113			
3					Flaw				
4				K			820		
5							860	777	
6							650		
7		3/10/15		H	325				
8					337	321			
9					302				
10				K			3180		
11							2790	2863	
12							2620		
13		3/31/15		H	401				
14					441	425			
15					433				
16				K			4040		
17							4590	4917	
18							5120		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:2 Cement Mortar MIX G1 20 % Lime

Normal Consistency 14.8 % Mixed March 5, 1915

Time of Set: Initial ——— hrs. Final: ——— hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	10:30	3/6/15	11	H	85				
2					100	91			
3					89				
4				K			540		
5							460	490	
6							470		
7		3/12/15		H	296				
8					301	299			
9					299				
10				K			2145		
11							2500	2088	
12							1620		
13		4/3/15		H	349				
14					397	371			
15					367				
16				K			2840		
17							3610	3130	
18							2950		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar — MIX A2 — 0 % Lime

Normal Consistency 10 % — Mixed March 10, 1915

Time of Set: Initial ——— hrs. Final: ——— hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	3/11/15	11	H	74				
2					97	85			
3					85				
4				K			640		
5							560	630	
6							690		
7		3/17/15		H	215				
8					200	225			
9					260				
10				K			2110		
11							1875	1862	
12							1600		
13		4/8/15		H	310				
14					284	286			29 day
15					263				test
16				K			1390		
17							1490	1690	29 day
18							2190		test
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA
MIX K2

1:3 Cement Mortar — 4 % Lime

Normal Consistency 10.3 % — Mixed March 31, 1915

Time of Set: Initial ____ hrs. Final: ____ hrs.

No	Hr. Mixed	Tested Date	Hr.	By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	11:30	4/1/15	11	H	71				
2					80	79			
3					85				
4				K			670		
5							720	617	
6							460		
7		4/8/15		H	266				
8					240	254			Eight day
9					255				test
10				K			1510		
11							1570	1807	Eight day
12							2340		test
13		4/28/15		H	305				
14					384	345			
15					Flaw				
16				K			2130		
17							3170	2537	
18							2310		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar — MIX J2 — 6 % Lime

Normal Consistency 10.4 % — Mixed March 31, 1915

Time of Set: Initial ——— hrs. Final: ——— hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	10:00	4/1/15	11	H	79				
2					57	63			
3					53				
4				K			660		
5							640	677	
6							830		
7		4/8/15		H	242				
8					205	225			Eight day
9					229				test
10				K			1610		
11							1250	1580	Eight day
12							1880		test
13		4/28/15		H	298				
14					284	290			
15					287				
16				K			2090		
17							2450	2323	
18							2430		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar MIX H2 8 % Lime

Normal Consistency 10.5 % Mixed March 29, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	11:30	3/30/15	11	H	69				
2					55	60			
3					57				
4				K			520		
5							630	567	
6							550		
7		4/6/15		H	223				
8					156	204			Eight day
9					233				test
10				K			1590		
11							1500	1623	Eight day
12							1780		test
13		4/26/15		H	233				
14					269	260			
15					279				
16				K			1710		
17							1500	1907	
18							2510		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar — MIX B2 — 10 % Lime

Normal Consistency 10.5 % — Mixed March 8, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	3/9/15	1:	H	78				
2					64	74			
3					81				
4				K			560		
5							580	543	
6							500		
7		3/15/15		H	227				
8					226	225			
9					222				
10				K			850		
11							1020	880	
12							770		
13		4/6/15		H	290				
14					290	295			
15					305				
16				K			2160		
17							2100	2303	
18							2650		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA
MIX C2

1:3 Cement Mortar 12 % Lime

Normal Consistency 11 % Mixed March 10, 1915

Time of Set: Initial ______ hrs. Final: ______ hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	12:30	3/11/15	11	H	56				
2					64	60			
3					Flaw				
4				K			350		
5							305	315	
6							290		
7		3/17/15		H	179				
8					160	177			
9					193				
10				K			1670		
11							1660	1593	
12							1450		
13		4/8/15		H	245				
14					219	245			29 day
15					270				test
16				K			1570		
17							2770	2150	29 day
18							2110		test
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar   MIX D2   14 % Lime

Normal Consistency 11.2 %   Mixed March 12, 1915

Time of Set: Initial ——— hrs. Final: ——— hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	10:30	3/13/15	11	H	84				
2					78	81			
3					Flaw				
4				K			570		
5							560	557	
6							540		
7		3/19/15		H	198				
8					183	187			
9					181				
10				K			1530		
11							1450	1397	
12							1210		
13		4/9/15		H	248				
14					252	251			
15					254				
16				K			2370		
17							3120	2630	
18							2400		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar   MIX E2   16 % Lime

Normal Consistency 11.5 %   Mixed March 15, 1915

Time of Set: Initial ______ hrs. Final: ______ hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	9:30	3/16/15	11	H	70				
2					82	69			
3					56				
4				K			540		
5							500	507	
6							480		
7		3/22/15		H	188				
8					180	179			
9					168				
10				K			1580		
11							1712	1577	
12							1440		
13		4/12/15		H	182				
14					212	218			
15					261				
16				K			1340		
17							2130	1710	
18							1660		
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar — MIX F2 — 18 % Lime

Normal Consistency 11.7 % — Mixed March 17, 1915

Time of Set: Initial———hrs. Final:———hrs.

No	Hr. Mixed	Tested			Tensile Stress		Comp. Stress		Remarks
		Date	Hr.	By	Briquette	Average	Cube	Average	
1	9:30	3/18/15	11	H	82				
2					68	74			
3					71				
4				K			520		
5							380	433	
6							400		
7		3/24/15		H	220				
8					193	201			
9					189				
10				K			1720		
11							1780	1693	
12							1580		
13		4/15/15		H	247				
14					303	277			29 day
15					282				test
16				K			3500		
17							2500	2673	29 day
18							2020		test
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

A STUDY OF THE EFFECTS PRODUCED ON PORTLAND CEMENT BY THE ADDITION OF VARIOUS PERCENTAGES OF HYDRATED LIME

By
Leonard D. Hook
and
Claude A. Knuepfer

LABORATORY DATA

1:3 Cement Mortar MIX G2 20 % Lime

Normal Consistency 12 % Mixed March 17, 1915

Time of Set: Initial——hrs. Final:——hrs.

No	Hr. Mixed	Tested Date	Tested Hr.	Tested By	Tensile Stress Briquette	Tensile Stress Average	Comp. Stress Cube	Comp. Stress Average	Remarks
1	12:30	3/18/15	11	H	40				
2					48	44			
3					Flaw				
4				K			310		
5							260	277	
6							260		
7		3/24/15		H	164				
8					183	169			
9					149				
10				K			1220		
11							1450	1400	
12							1530		
13		4/15/15		H	206				
14					228	210			29 day
15					197				test
16				K			1880		
17							1930	1933	29 day
18							1990		test
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									

PAT

No	Test	Remarks
1	Normal in air	
2	Normal in water	
3	Accelerated	

Remarks:

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